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et *Société Royale Entomologique d'Egypte (1922 - 1937)*

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PLACÉE SOUS LE HAUT PATRONAGE DU GOUVERNEMENT EGYPTIEN
PAR DÉCRET ROYAL EN DATE DU 15 MAI 1923

LE CAIRE

IMPRIMERIE FRANÇAISE

1954

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The effect of carbon-dioxide upon the wing-beat frequency of *Drosophila virilis* Sturtevant (1916)

[Diptera : Drosophilidae]

(with 12 Text-Figures)

by A. Aboul-Nasr, M.Sc., Ph.D.,
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CONTENTS

I. Introduction. — II. Material and methods. — III. The effect of fatigue. — IV. The effects of variation in environmental temperature. — V. The effect of higher percentages of carbon-dioxide in the air of the flying insect. — VI. The effect of low oxygen concentration upon the rate of wing-beat. — VII. Conclusion and summary. — VIII. Bibliography.

I. INTRODUCTION

As is well known, the pitch of a tone is dependent on the frequency of vibrations of a vibrating object ; likewise the pitch of a flying tone is dependent on the frequency of wing-strokes of an insect.

On studying the literature concerning the biology of flying, the writer noticed that in spite of the many papers, rather slight importance was attached expressly to the frequency of the flying tone. The results obtained by different methods were partly correct and reliable, it is true, but the number of results were very few. This has possibly been caused by the impracticability of the available methods.

The research series was started in the last century by Marey (1869). Among other things, he determined the wing-beat frequency of some of the most common insects employing a « graphical method », an earlier stage of the so-called Kymograph, which is nowadays in use in many fields ; the wing of a fixed insect functioned like a Kymograph needle writing on a rotating sooted cylinder ; one could measure and count the frequency from

the number of the vibrations of the wings, compared with a certain constant. During about twenty years Marey continued with various flying-biological studies especially on birds, and in one of his later publications (1890) when the possibility of using photography was increasing, he describes two other methods for the determination of the frequency of the wing-strokes particularly with regard to birds, namely the chronographical and the stroboscopical methods.

Marey made his studies solely from a biological point of view, and the methods he employed were completely mechanical. At the same time Landois (1874) published his sound-physiological observations. Written by a person with a thoroughly musical sense, and discussing various sound utterances in the animal kingdom, his very pertinent and many-sided studies are in this respect the most important and fundamental of their kind. Landois determined among other things the pitch of the flying tone of about twenty insects through an « acoustic » method. He took through the tuning fork a certain pitch, and by singing he could analyze the interval between the tone of the flying insect and the tone of the tuning fork. Landois came thus, as a musically inclined observer, to treat the subject also from an acoustic and musical point of view.

The next research work, discussing the tones and the vocal organs of insects more widely, is the publication of Prochnow (1907). His studies concerning the flying tones of insects in the first place are based on the before mentioned works by Marey and Landois. In addition, he describes his own « mechanical » method of determining the frequency. According to this he deduces on the basis of physical facts a certain formula, by means of which he mathematically determines the probable frequency, taking into consideration as known factors the weight of the body, the surface of the wing, and the distance of the center of gravity of the wing from the axis. Instead of the last mentioned not easily determinable factor he uses without greater error the easily determinable length of the wing.

In 1911 Axenfeld published a short but good work in which he has employed a more advanced kymographical method, and in 1914 Voss published a pertinent research-work in the field. This is, in addition to Landois, the only extensive early publication on the subject. Voss employed in the first place the chronophotographical method created by Marey and advanced by several authors (Bull, V. Lendenfeld), with regard to fixed as well as free flying insects, in the first place insects flying away. This research work is undoubtedly the most extensive, reliable, pertinent, and many-sided of all the earlier studies published in the field.

Since 1932 there is the short study of Magnan and Sainte-Lague, with a formula like that of Prochnow, which, however, is much more

correct. The authors consider the flying movement as a complicated resultant movement or summation, which they divide into active and passive factors. From these ideas, supporting by the rules of aerodynamics, they deduce a suitable formula, by means of which the probable frequency is calculated. In 1934, a Norwegian, Schnell-Larsen, published a study of the field, and describes a new method ; he lets the insect fly through a special apparatus, which is connected with a microphone transmitting the vibrations into a recording galvanometer leaving a tracing on a moving film. Calculating the results as a « constant » a curve describing the number of cycles of alternating electrical current was used, photographed on the same film. He revised the results by letting a ray of light, directed upon a photo-electric cell, go through the fixed insect's wing in motion. By means of that apparatus one could also determine the flying speed of the insect, which like the angle of flight slightly influenced the frequency of wing vibration of the insect under experiment (*Apis mellifica* L., male).

Oehmichen (1920) appears to have been the first worker who made much use of the stroboscope for the visual study of insect flight. By these various methods, the workers Landois, Marey and others were able to recognize the existence of variation in the wing-rate of a species or of an individual insect. There has been a tendency among these workers to assume that there exists a definite rate which is natural to each species and that any variation represents a departure from the normal.

Chadwick (1939) using the stroboscopic method, studied the variation of the wing-rate in *Drosophila* due to various factors such as fatigue and environmental temperature. He was able to prove that the variation of wing-rate in *Drosophila* depends upon the ration between the volume of the thoracic flight muscles and the size of the wings. If the muscle volume is held constant, the wing-beat frequency increases uniformly as the wing size decreases.

Sotavalta (1947) showed that in certain small midges the frequency of wing beat is above 1000 beats per second. Frequencies in the region of 150-300 beats per second are commonly found in the larger Diptera (*Calliphora, Musca, Eristalis*). Even the lower figures represent a rate of muscular action far higher than is found elsewhere in the animal kingdom ; a frequency of 1000 beats per second involves a complete cycle of contraction and relaxation in 1 msec.

Sotavalta, after a series of experiments on the effect on the frequency of wing beat of altering the air pressure and the loading on the wings, concludes that the inertia of the wing is the main factor controlling the beat frequency. Pringle (1949) reached the conclusion that the effect of loading

on the frequency of the wing beat and haltere oscillation of Diptera is a property of the indirect flight muscles, and is not a reflex phenomenon. The indirect flight muscles of *Calliphora* cannot be made to contract by electrical stimulation after exposure by the vertical bisection of the thorax. P r i n g l e proved by various experiments that the frequency of contraction of the muscles is not determined centrally in the ganglion, but is controlled directly by the loading upon them.

« The Songs of Insects » by P i e r c e (1948) presents good methods and instruments to record the various sounds produced by the insects. His book is profusely illustrated with photographs of the insects, micrographs of their sound-making mechanisms and reproductions of the sound records themselves.

II. MATERIAL AND METHODS

Drosophila virilis was selected for these experiments because of its convenient size and ease of rearing and handling. Other species proved to be less co-operative in the flight test.

The method of measuring the wing-beat frequency is based upon C h a d w i c k ' s idea of using the stroboscopic light. A description of the stroboscopic technique for measuring wing-beat frequency has been given by C h a d w i c k (1939). In short, the stroboscope consists of neon-filled tube arranged in a tuned circuit so that the flash frequency is instantly adjustable over a range of 1500 to 18000 flashes of light per minute. Since there is no after glow, any cyclical movement, such as that of the insect wing can be brought to an apparent standstill when the flash frequency of the instrument is tuned to equal exactly the frequency of wing movement. The calibrated scale then gives the frequency directly.

The insect is held by means of a wire loop which is fastened around its neck leaving the whole body free from any other support. The wire loop is carefully adjusted so as not to cause any physical damage to the insect. Insects whose flight responses were evidently affected by the nature of the mount were discarded especially those which did not take to flight as soon as they were stimulated.

Setting the very fine wire around the neck of the insect is done by introducing the insect into a narrow glass tube (Fig. 1) which has an outlet wide enough to allow the passage of the body. With the help of a glass rod placed opposite to the opening of the glass tube only the head of the fly is allowed to extend beyond the end of the tube (Figs. 2 and 3).

By very careful technique and a little practice a wire loop can be fastened around the neck of the fly without any injury to its tissues. All this is done

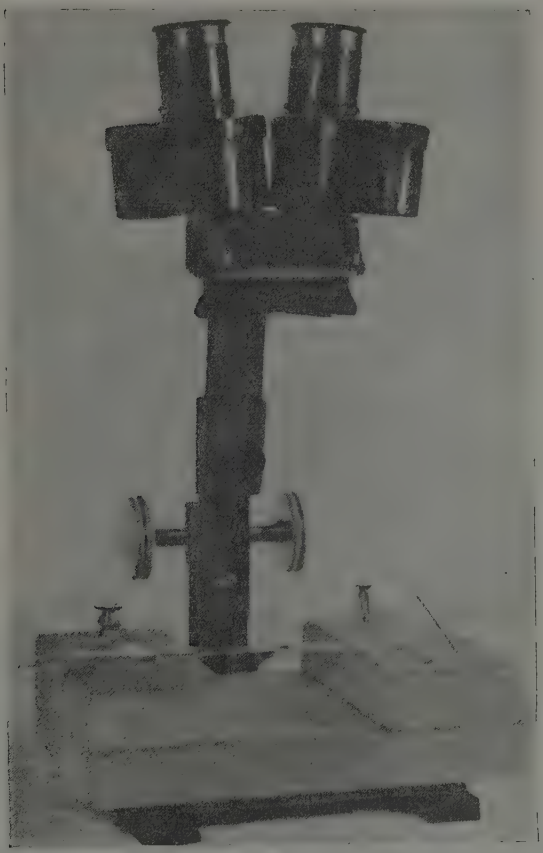

Fig. 1 : Equipment used in mounting the flies for flight tests.

Fig. 2 : *Drosophila virilis* with head protuding from glass tube.

under the binocular microscope. The fixed insect can now be placed in the flight chamber letting its feet settle upon the platform (Fig. 4).

The insect can always be stimulated to fly by the sudden removal of the platform from under its feet. This is done quite satisfactorily by the help of an electromagnet. The flight chamber is held in an air thermostat.

For the source of carbon dioxide and nitrogen, tanks of these gases were available. An air compressor provides the source of air.

Carbon dioxide and air or nitrogen and air are mixed in various ratios required for the run of the experiment by running the compressed commercial product from the tank through a calibrated capillary flowmeter which measures the volume of the gas delivered per minute. The compressed air

Fig. 3 : A mounted *Drosophila virilis* with the wire loop around.

was regulated through a similar flowmeter and the bases were allowed to mix in a large jar before being introduced into the flight chamber.

Specimens of *Drosophila virilis* were selected at random from a stock that could be freshly emerged or several days old.

It is evident that the general behavior of insects and hence presumably their wing-rate is influenced to a large extent by sensory stimuli. For this reason the observation on fixed specimens were made regularly with the least illumination possible, other than the light of the stroboscope. The intensity of this light varies slightly with the frequency, an unavoidable difficulty, but such variation had no observable effect on the wing motion. Check experiments with varied intensities were likewise negative. Unnecessary shocks and movements were avoided during the tests.

The apparatus emits a constant hum of the frequency to which it is tuned, but no response to this or other noises as that of the air compressor, was observed at any time with this species.

The responses of *Drosophila virilis* to tactile stimulation during flight are varied. Flight ceases regularly when contact is made with the tarsi, but the tibiae and femorae may often be touched with a needle without evoking this response. Touching regions of the abdomen or thorax, or even interfering with the wings, may lead to an irregular increase in the wing-rate,

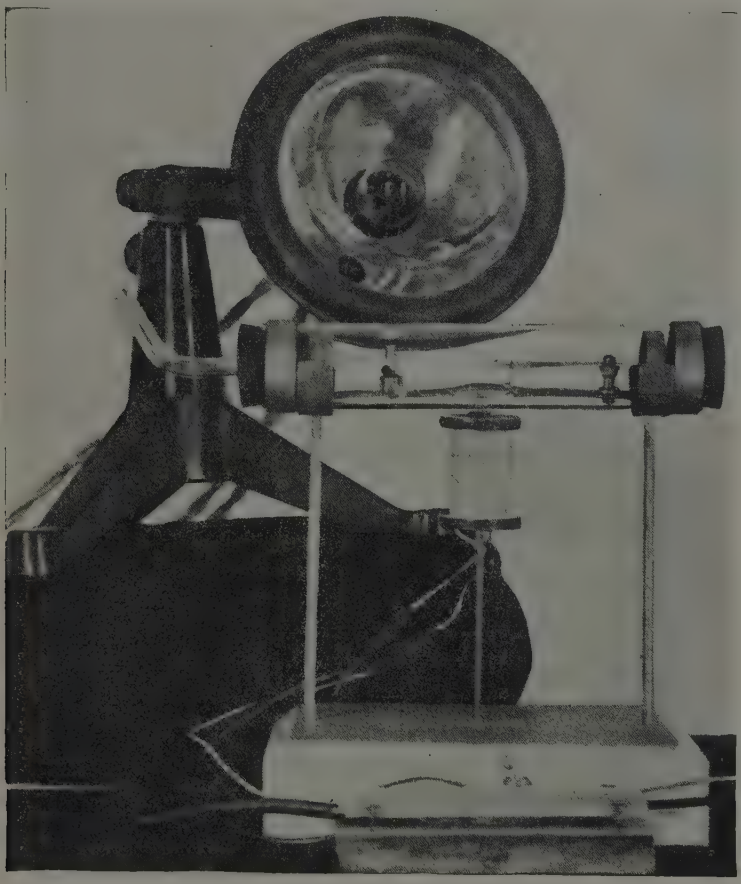

Fig. 4 : The fumigation chamber showing a fly resting upon the platform.

followed, on continued stimulation, by the inhibition of flight and the onset of other responses evidently directed toward evasion. If the head is touched or objects brought near it the forelegs are usually stimulated into movement. Flight is inhibited if the insect succeeds in grasping an object. Interesting

is the fact that a flying fixed insect brought near another similarly fixed but not flying insect, usually results in stimulating the second to fly within close range of the wing-rate of the first insect.

It was always preferable to let the insect rest upon the platform for a few minutes after being fixed inside the flight chamber before any reading was attempted. This period of time assures the formation of the tarsal reflex in the fly, so the sudden removal of the bar readily stimulates the flight of the insect.

In the majority of the cases the highest frequency of the wing-rate is not reached at the start of the run as C h a d w i c k (1939) stated. It is found in this species that the maximum rate occurs after the first minute or so.

III. THE EFFECT OF FATIGUE

Specimens of *Drosophila virilis* mounted as described are stimulated to fly by means of the tarsal reflex. Sometimes it is necessary to stimulate the insect once or twice by opening and closing the circuit leading to the electromagnet thus depressing and then releasing the platform. Flight

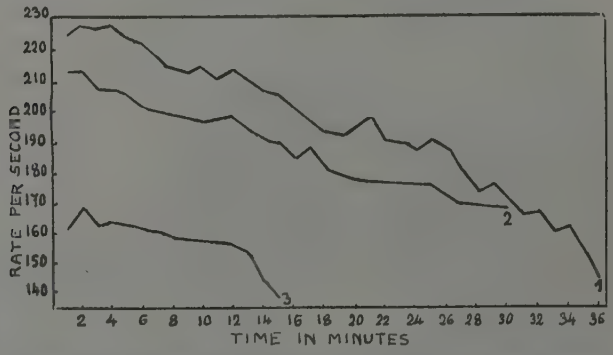

Fig. 5 : Variation in wing-rate of *Drosophila virilis* during continuous fixed flight.

continued until it ceases spontaneously. Lighting was with the strobotron only. Wing-rate observations were taken at one minute intervals. The temperature was held constant at 25° C.

The longest record of continuous fixed flight obtained in this species was 36 minutes. Records of cases over 25 minutes are not uncommon, but many cases were met where the insects cease to fly after the first few minutes.

At the end of such experiments of long flight, the specimens could be induced to fly again but only at low rates and usually for only a few seconds at a time. Yet there were some cases where the insect was able to fly again for another period of time equal to that of the first test. The final rate-level lies at about 70-75 % of the starting level in most cases (Fig. 5).

Chadwick (1939) states that the final rate level in case of *Drosophila repleta* lies at about 50-60 % of the starting level, yet Marey (1869) stated that when his specimens had become fatigued after a long experiment, the rate fell to a fourth or a fifth of the previous figure. If the insects were then freed, their flight was slow and of short duration. He also found that in fresh specimens the rate might vary by as much as 3:1. Magnan (1934) noted a reduction of 33 1/3 % in wing-rate during photographic experiments with *Macroglossa stellatarum* (a sphingid) and attributed it to fatigue.

The effect of constant flow of air upon the wing-rate.

It was clearly noted that air currents can stimulate the flying insect towards increasing its rate of wing-beat. Some authors even classify air

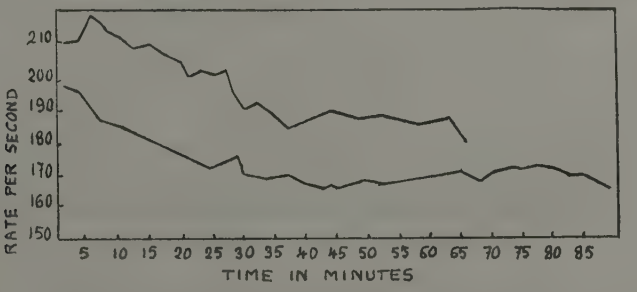

Fig. 6 : Variation in wing-rate of *Drosophila virilis* under continuous flow of air.

currents in the category of tactile stimuli (Fraenkel 1932, Von Buddenbrock and Friedrick 1932, Hoffmann 1936). By using a flow of air running constantly from an air compressor to the flight chamber, the author was able to get considerable data concerning not only the sudden increase in the wing-rate but also the length of the duration of the period of continuous flight (Fig. 6).

The air stream passing through the flight chamber was averaging a rate of 0.27 miles per hour. The start of the flow was combined with the sudden depressing of the platform.

IV. THE EFFECTS OF VARIATION IN ENVIRONMENTAL TEMPERATURE

Since the effect of temperature upon flight was a secondary part of this experiment, only few tests were made to show whether *Drosophila virilis*

wing-rate is influenced by environmental temperature or not. The temperatures selected are : 20, 25 and 28° C.

Experiments for these tests were conducted and they all confirm beyond doubt that *D. virilis* wing-rate is definitely influenced by the environmental

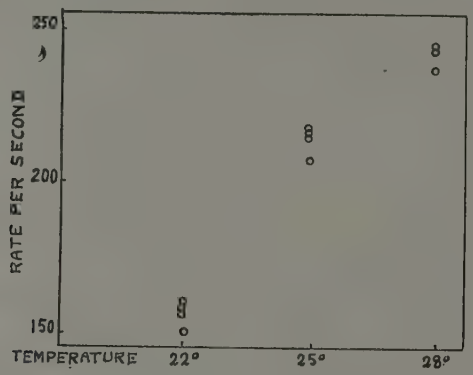

Fig. 7 : Variation in wing-rate of *Drosophila virilis* with varying temperature.

temperature. Ten flies are taken for the flight test at each temperature. An average of ten readings were taken for each insect with an interval of one minute between successive readings. The insects are selected at random from the stock which is kept overnight at the selected temperature (Fig. 7).

V. THE EFFECT OF HIGHER PERCENTAGE OF CARBON-DIOXIDE IN THE AIR OF THE FLYING INSECT

Carbon-dioxide has attracted the attention of many workers in the field of animal physiology, as to its effects upon the various systems of the body. Taking flight as a measure of the activity of the systems of the body and being dependent on the interaction of most of these physiological systems, one would expect changes of these systems to be reflected in the wing-beat frequency.

Experiments

Drosophila flies were selected for these tests at random from the stock which was kept in a regulated thermostat at a temperature of 25° C. Great care was always taken to select normal and healthy insects for the various flight tests. Before introducing the insect into the chamber on the platform, the proper gas mixture was permitted to run for some minutes to assure the total replacement of the atmospheric air. A constant flow of air and the required percentage of carbon-dioxide was allowed to mix thoroughly in a

large jar with three openings : one inlet for air, another for the carbon-dioxide and the third an outlet for the mixed gas which then passes through a rubber tubing to the flight chamber (Fig. 8).

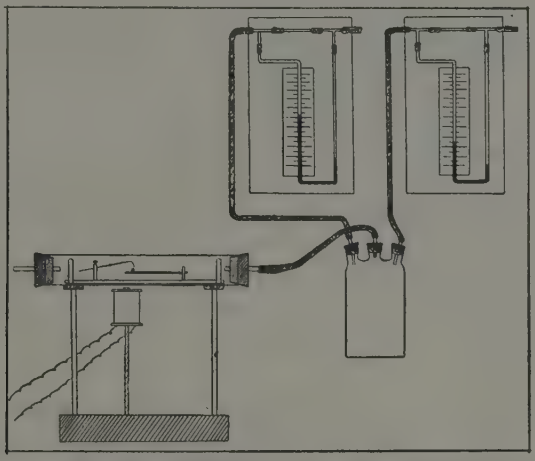

Fig. 8 : Diagram showing method of preparing different atmospheres for the flight tests of *Drosophila virilis*.

By using two calibrated flowmeters, the rate of flow of the gases is held constant and at the required ratio all during the time of the test.

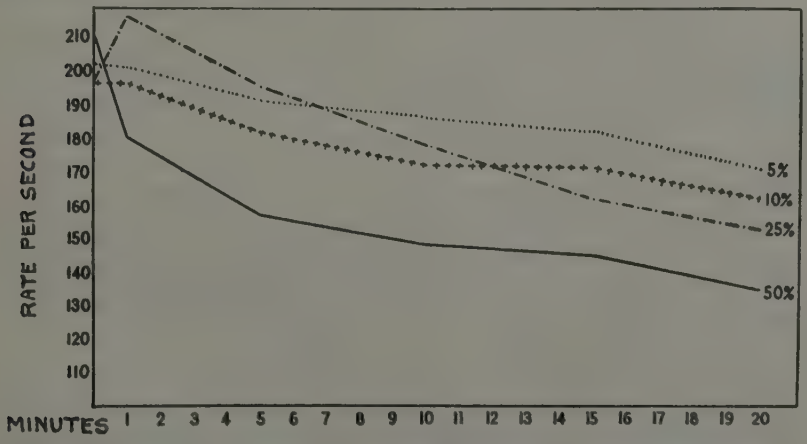

Fig. 9 : Effect of CO_2 upon wing-beat frequency of *Drosophila virilis*.

In each experiment, with every required percentage of carbon-dioxide, five tests were conducted. Readings were obtained on each insect separately,

first reading in the normal atmospheric air, then within the first minute after the flow of the mixture, then after each five minutes for a total of 20 minutes. Two successive readings were taken for each time interval. Repeating the previous tests each time on five insects chosen at random from the stock, record was made of the results obtained after subjecting the insects to increasingly high percentages of carbon-dioxide which ranged from 5 up to 50 % (Fig. 9). From the collected data one can see quite plainly that carbon-dioxide has a significant effect upon the rate of frequency of the wing-beat of *Drosophila virilis*.

For low ratios of carbon-dioxide, such as 5 %, the significance as expressed in terms of a drop in the frequency of wing-beat between the starting level and the level at the end of 20 minutes, is not very great. As one increases the percentage of CO_2 in the mixture it becomes obvious that it depresses the rate of flight until we reach the 15 % level of carbon-dioxide where the first minute exposure will induce an increase in the frequency rather than a decrease.

This sudden increase in the frequency of the wing-beat is only shown between 15 and 25 % of carbon-dioxide. Above 25 % CO_2 the rate of wing-beat falls continuously and does not show the initial increase for the first minute ; the drop of rate of wing-beat increases here with the percentage of carbon-dioxide mixed in the air.

Insect behavior when mixed air and carbon-dioxide is introduced.

In the low percentages of the gas, the insect seems to fail to respond to the presence of carbon-dioxide and it apparently behaves normal. It responds rather readily to the depression of the platform bar, starting its flight action.

The effect of fatigue is overcome by taking the reading as quickly as possible within a few seconds of the start, then letting the platform up again forcing the insect to stop and rest upon it.

No doubt because of the natural variation in rate, it is often difficult to retain a « standing image » over any extended period. The insect was always ready to continue flying if allowed to do so by keeping the bar away from the reach of its feet.

A few efforts are made by the fixed flies to move around pulling the flexible wire by walking a limited area on the platform. Some of the flies, fixed to the wire, even took jumps in the air trying to fly away. These struggles are not as noticeable when the ratio of carbon-dioxide introduced is increased ; up to 25-30 %, the insects then do not attempt to move or even shift their feet on the supporting bar. Forty to 50 % of carbon-dioxide

hinders any movement of the insect appendages. The insects are difficult to stimulate for flight tests at these ratios unless they are given several pushes by the platform. This retardation in response to the tarsal reflex starts to show at the ratio of 30 % carbon-dioxide.

The effect of carbon-dioxide upon the duration of continuous flight of Drosophila virilis.

To find out the influence of carbon-dioxide upon the frequency of wing-beat under the condition of continuous fixed flight, several tests were carried, the results of which confirm the idea that carbon-dioxide is a retarding agent so far as the rate of wing-beat of *Drosophila virilis* is concerned. The com-

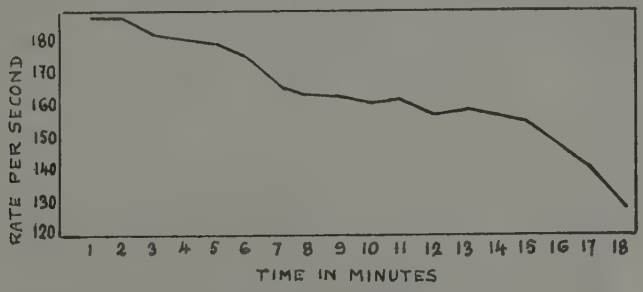

Fig. 10 : Wing-rate of *Drosophila virilis* during continuous flight under 20 % carbon-dioxide.

bination of the effect of fatigue and that of the gas is so great that it actually drops the frequency of wing-beat way down before the insect stops spontaneously. The graph (Fig. 10), shows a typical example obtained by setting an insect to fly continuously in a mixture of 80 % air and 20 % carbon-dioxide.

Duration of continuous flight under various percentages of carbon-dioxide.

Flies selected at random from the stock, were allowed to fly continuously in the mixture of carbon-dioxide and air. The required mixture was allowed to pass for a few minutes the flight chamber to assure the complete replacement of the air before the introduction of the fixed insect. Special effort was taken to start the flow of the air with the sudden dropping of the supporting platform from under the feet of the insect thus inducing its flight.

Readings for the wing rate frequency were taken every minute without letting the insect stop flying until it stops due to fatigue or any other factor. The duration of continuous fixed flight is thus recorded. The author was

not able to run the various concentration tests of the gas upon the one and the same insect, as each insect by the end of every test becomes too exhausted to run another test.

Five insects are taken for each percentage of carbon-dioxide. By averaging the results obtained the representative graph gives the relation we want.

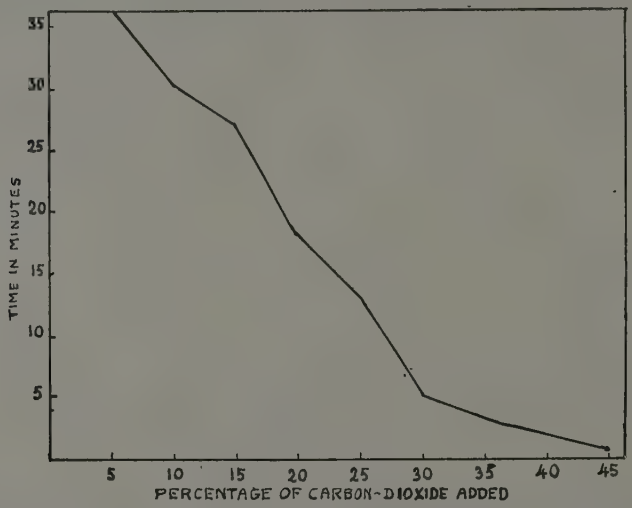

Fig. 11 : The effect of carbon-dioxide upon duration of continuous flight of *Drosophila virilis*.

Increasing the amount of carbon-dioxide in the atmosphere of the insect, causes the duration time of continuous flight to decrease (Fig. 11).

VI. THE EFFECT OF LOW OXYGEN CONCENTRATION UPON THE RATE OF WING-BEAT

It was thought at first that the effect of CO_2 upon the rate of wing-beat of the insect might be caused due to decreasing the total oxygen concentration in the atmosphere of the flying insect. It is quite interesting to compare results obtained due to the introduction of carbon-dioxide, with those of low oxygen concentration.

Running the experiments under practically the same conditions it was possible to record some significant differences. From the data obtained, and their representative graph (Fig. 12), it is seen that by lowering the oxygen concentration of the air by adding the corresponding amount of nitrogen, like carbon-dioxide, this shows the significant decreasing effect upon the

frequency of the wing-beat. This does not however stimulate the insect to increase its wing rate at the first few moments of exposure to the mixture as the corresponding low percentages of carbon-dioxide do.

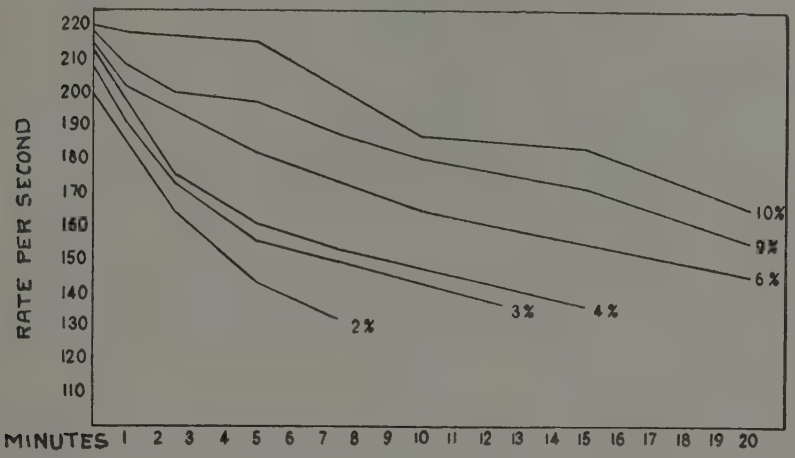

Fig. 12 : Effect of decreasing total oxygen concentration upon wing-rate of *Drosophila virilis.*

Amazingly enough, some of the insects were able to maintain their average rate of wing-beat for a long time in spite of the very low percentage of oxygen in their atmosphere due to the added amount of nitrogen

Insect behavior under the effect of lowering the oxygen concentration.

The insect, exposed to an atmosphere of low oxygen concentration seems to be, on the average, more active than it is when exposed to carbon-dioxide. On decreasing the oxygen concentration a little, the fly is still vigorously moving around on the supporting platform to the extent which is allowed by the fixing wire. It even makes some attempts to start flight without the depression of the bar. The insect readily responds to the tarsal reflex in cases when total oxygen concentration of the air is lowered due to the addition of nitrogen, to 15 %. In further decreasing the total oxygen concentration the insects are less co-operative in responding to the flight reflex, for the author found some difficulty in stimulating the insects to fly, even by bouncing the bar several times under their feet.

Another quite prominent characteristic in the insect behavior is the death feigning phenomenon which the fixed insect practices on the platform, when the total oxygen concentration is lowered to 10 % or less. The bar can be depressed and returned several times before the insect gives signs of life

by starting the vibration of its wings and for a very short period. The duration time of continuous flight decreases as the total oxygen concentration in the air decreases.

VII. CONCLUSION AND SUMMARY

The factors for variation in rate which have been subjected to study during these experiments may be classified in two groups on the basis of magnitude of their effect. Some factors such as tactile stimuli seem to cause rather temporary fluctuations within narrow limits of the basic rate. The level of this basic rate is determined by processes which are unknown but which presumably affect the whole organism and not only the flight function.

Fatigue may be supposed to have a more direct effect on the flight mechanism. Temperature no doubt has a quite significant effect upon the rate of wing-beat of *Drosophila virilis,* the higher the temperature the greater the increase in the frequency of the wing movement within the favorable range of temperature.

As far as the effect of carbon-dioxide is concerned, one can judge that it has certain influences upon the rate of wing-beat.

(1) In lower percentages of carbon-dioxide, up to 25 %, this, at the first few moments causes an increase in the frequency before it affects the insect to decrease its rate of wing movement.

(2) If higher ratios of the gas, carbon-dioxide, are allowed to affect the rate of flight, these usually cause a slowing down of the activity.

In case of substituting nitrogen for carbon-dioxide, the nitrogen being inert, the effect is thus due to lack of oxygen in the atmosphere of the fly.

The effect of decreasing the total oxygen concentration in the chamber will cause the rate of wing-beat to decrease to a certain degree yet not as much as that of the corresponding percentages of carbon-dioxide.

This retardation in the rate of flight due to low oxygen concentration is not preceded by any increase in the rate of wing-beat as in case of low percentages of carbon-dioxide.

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The effect of carbon-tetrachloride upon the wing-beat frequency of *Drosophila virilis* Sturtevant (1916)

[Diptera : Drosophilidae]

(with 4 Text-Figures and 3 Tables)

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CONTENTS

I. Introduction. — II. Some observations on behavior of *Drosophila virilis*. — III. Halteres and problem of flight in *Drosophila*. — IV. Methods and material. — V. Insect behavior under CCL_4 exposure. — VI. Effect of carbon-tetrachloride upon adult *Drosophila virilis*. — VII. Effect of starvation upon wing-beat frequency. — VIII. Effect of CCL_4 upon rate of wing-beat at continuous flight. — IX. Conclusions. — X. Bibliography.

I. INTRODUCTION

Wing-beat frequency expresses usually the intensitv of the flight activity under normal conditions. Since flight is dependent on the interaction of most of the physiological systems of the insect, one would expect changes in these systems to be reflected in the wing-beat frequency.

In 1947 the author made some studies upon the effect of various factors upon the wing-beat frequency of *Drosophila virilis*. Among these factors were the effect of fatigue, temperature, high concentrations of carbon-dioxide in the atmosphere of the insect and low concentrations of oxygen.

The purpose of this present work is to study the effect of carbon-tetrachloride upon the wing-beat frequency of *D. virilis*. Various concentrations of the fumigant were used in these experiments.

Throughout the literature an enormous amount of work has been done on the action of fumigants and insecticides upon different insects. The workers used various methods in approaching this problem ; some worked

out the percent of mortality among different insects due to the effect of certain fumigants. Others studied the recovery period of insects in relation to the fumigant under test. Likewise the stupefaction period of many insects was taken as a measure for the degree of toxicity of the fumigant upon the insect investigated.

The author was not able to locate throughout the literature any work which suggests the usage of the wing-rate of insects as a sensitive measure to study the effect of fumigants upon insects.

This present work was based on the idea of using this method beside making a comparative study of some of the above methods.

II. SOME OBSERVATIONS ON BEHAVIOR OF DROSOPHILA VIRILIS

Working for over 2 years with *D. virilis* the author thought it desirable to mention some of the peculiar behavior of the flies that are studied during the work. Some of these are quite abnormal from the natural behavior of these insects. On several occasions, the worker met with flies that looked normal and healthy yet acted strangely concerning their flight behavior. These flies walk on flat objects with their wings in a state of flight, i.e. vibrating almost within the same range of wing-beat that they exert in real free flight.

Other flies, when mounted in the flight chamber to record their rate of wing-beat, behaved peculiarly, using only one wing for flying and the other wing remaining quite motionless resting on the dorsal side of the body. The wing-beat frequency of the wing in action proved to be of the same rate that this species gives under normal conditions. Sometimes one wing is in full motion while the other is barely vibrating in a narrow angle, making jerks every once in a while. This phenomenon also proved on several occasions to be reversable in both wings.

On several occasions some insects were left mounted to the wire loop for twenty-four hours away from any possible source of food, and, yet, on the next day they were as ready to fly as if freshly mounted.

III. HALTERES AND PROBLEM OF FLIGHT IN DROSOPHILA

It was considered in Diptera that halteres are an atrophied second pair of wings, that they have nothing to do, so far as the actual flight mechanism is concerned ; at least that was the view taken and believed by various early entomologists. In addition to their functions as organs of equilibrium, the halteres of Diptera have been regarded as important stimulatory organs. Buddenbrock (1919) supposed that the chordotonal and campaniform sensilla which they carry are stimulated by their vibratory movements

and that these stimuli facilitate the conduction of the reflexes concerned in flight. Fraenkel (1932), working on nervous co-ordination of insects during flight, observed that suspended flies continue flying for a much shorter time after each stimulus if the halteres are removed. Ulrich (1930) found in Strepsiptera where the fore wings have become similarly transformed into club-shaped halteres richly supplied with campaniform sensilla, that when they are amputated the insect loses the power of flight and finally the hind wings stay at rest. Fraenkel and Pringle (1938) have shown that during flight the halteres are « vibrating rapidly through an arc of about 90 degrees in the vertical plane ». More recent investigations employing high speed photography have confirmed the observations of Fraenkel and Pringle, and have also indicated that the halteres normally move in the same rhythm as the wings, but in the opposite direction.

The author, working on the flight problem and the variation of wing rate under various effects of fumigants, tried to notice the apparent movements, if any, of these organs during flight. Placing *Drosophila* flies under high power of magnification to notice the position of wings, legs and other parts of the body during flight, to the author's amazement the halteres were in a very high rate of vibration, which caused them to nearly escape detection under the microscope. This confirmed other workers in that they might play a role in the mechanism of flight.

After carefully managing to devoid the insect of one of its halteres, it was noticed that the insect could not behave normally. The wing on the side of the missing haltere dropped down beside the body while the wing on the opposite side rested on the back of the fly. Depriving the fly of both its halteres resulted in losing balance on its feet, taking only jumps in the air, unable to show any power of flight. This repeatable experiment shows that the halteres of *Drosophila* have a major role in the mechanism of flight.

Using the house fly, *Musca domestica*, in the same test, the removal of one or both of its halteres did not apparently affect the insect, as it behaved quite normal. The insect was able to fly readily, if induced, and also the rate of its wing-beat remained at the same level it shows under normal conditions.

IV. METHODS AND MATERIAL

The same procedure used in experiments conducted to test the effect of CO_2 upon the wing-beat frequency of the fly (see previous paper in this Bulletin) has been used in these experiments.

For varying the concentrations of the fumigant, air was allowed to bubble through columns of liquid carbon-tetrachloride at room temperature and, by the aid of calibrated capillary flowmeters, the amount of saturated

air delivered could be measured in litres per minute. Knowing the vapor pressure of carbon-tetrachloride at that temperature, its concentration in grams per liter was calculated thus using the equation :

$$\text{Total concentration in grams per liter} = \frac{\text{vapor pressure}}{760} \times \frac{237}{273 + t} \times \frac{1}{22.4} \times \text{Mol. wt.}$$

The gases were allowed to mix in a large jar before being introduced into the flight chamber (Fig. 1). Specimens of *D. virilis* were selected at

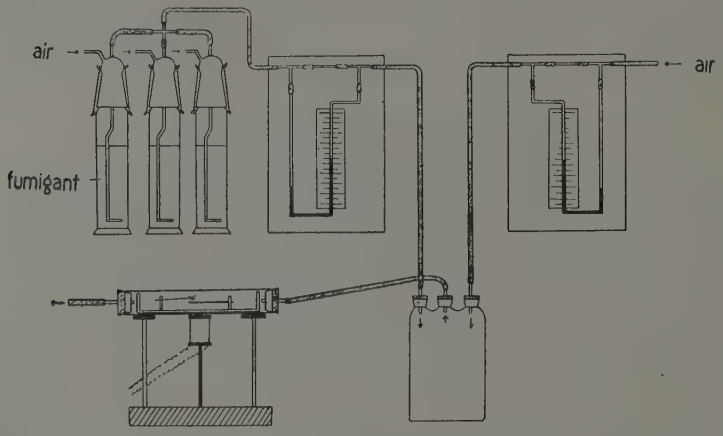

Fig. 1 : A diagram illustrating method of preparing various atmospheres for the flight tests of *Drosophila*.

random from a stock which was kept in an air thermostat at room temperature.

The fumigant for study, carbon-tetrachloride, was selected because of its advantages ; being non-inflammable and less toxic to humans. Its ease of handling, due to its physical properties, was also encouraging to the author. Pure liquid carbon-tetrachloride in quantities is always available.

V. INSECT BEHAVIOR UNDER CCL_4 EXPOSURE

Subjecting one insect at a time to the effect of the toxic action of the fumigant at a concentration of 0.54 gram CCL_4 per liter of air, the animal started to show normal rate of flight near 220 D.V./S. After an average period of exposure of fifty seconds to the continuous flow of the fumigant mixture, the insect stopped its continuous flight, yet flying and stopping alternately for a period of four minutes. It was clearly noticed under these conditions that there was a difference in the position

and angle of the wings during flight. Under normal conditions the tip of the wing of *Drosophila* forms the well-known figure « 8 ». while under the fumigant action the tips of the wings only complete the lower loop of the figure « 8 » with a small fraction of the upper loop. After five minutes or so of running the test the insect stops totally the movement of its wings, which stays in a different way from the normal resting position, showing a variation in the position of the wings ; that is, either both wings are stretched down and backwards or one wing up and one wing down. The legs, showing still very evident, yet feeble movements, are, all of them, stretched away from the body. Regarding the abdominal part of the insect, vigorous telescopic movements of the segments were noticed, accompanied by a twisting of the posterior tip of the abdomen ventrally and forwardly. Generally, during these tests, the insect is noticed to emit a droplet of fluid from the posterior end of the abdomen. The proboscis, retracted in insects at rest, is noticed now to protrude and retract alternately until the stupefaction period when it remains extensively protruded.

Recovering period

Taking the insect away from the fumigation chamber and placing it under the high magnification of the binocular microscope to record any observations during its recovery stage, the author was able to follow any signs of movements made by the insect until it regained its resting stage. The tips of the legs started vibrating from the claws up through the tarsal segments. The first legs to regain their normal resting position were the front legs. They began very slowly to withdraw toward the body, still with their tips vibrating. At the same time the wings started to come close to the body and to each other. The second or middle pair of legs, after about one minute or so, gained their relaxed resting position. The last or third pair of legs were the last to recover and re-gain their normal withdrawn shape. By this time the wings are resting on the back of the insect in their normal overlapping position. During the whole period of recovery the abdomen of the insect is contracting in a peculiar spasmodic movement, and the proboscis is drawn back and retracted. During the recovery time the antennae of the insect are seen to vibrate in co-ordination with the similar movements of the legs.

A few minutes later the insect is ready to take flight by the least stimulus ; that is, by touching suddenly the tip of the legs, moving the fixed insect through the air or even touching slightly the head with the tip of the forceps.

This sequence of recovery from the anterior end of the body towards the posterior end is convincingly within pattern.

VI. EFFECT OF CARBON TETRACHLORIDE UPON ADULT DROSOPHILA VIRILIS

Flies were selected at random from the stock which is kept under a temperature of 25° C.

After mounting each fly in the flight chamber for the test, it is allowed to rest for a few minutes to acquire the tarsal reflex and to fly readily whenever the platform is dropped from under its feet. First, recording the wing-rate of the fly under the normal condition, then the toxic mixture of carbon-tetrachloride in the required concentration is allowed to mix thoroughly with air in a large jar before being introduced to the fly under the test. Some flies readily react to the dropping of the platform and enable the ob-

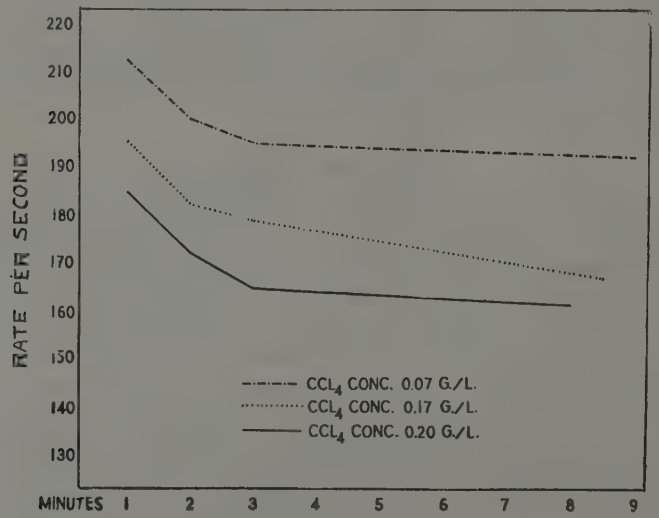

Fig. 2 : Effect of CCL_4 upon the rate of wing-beat of *Drosophila virilis*.

server to record easily the wing-rate ; yet many others required many stimuli before being induced to fly and even many were discarded completely after proving to fail to record and wing movement. The effect of carbon-tetrachloride upon these flies is quite different from the effect of increased percentage of carbon-dioxide in the atmosphere of the insect. The latter tends to agitate the fly, at least in the first moments, and induces it to record a higher rate of wing-beat. The effect of CCL_4 is different in that it considerably slows down the active movements of the wings right from the first moment. The fly shows, under the toxic action of the fumigant, no signs of vigorous movements except the very feeble movements of the legs. When

induced to fly, it does so for a very short interval of time, which does not exceed a few seconds.

The decrease in the rate of wing-vibrations corresponds with the increase in the concentration of the fumigant measured by more litres per minute of

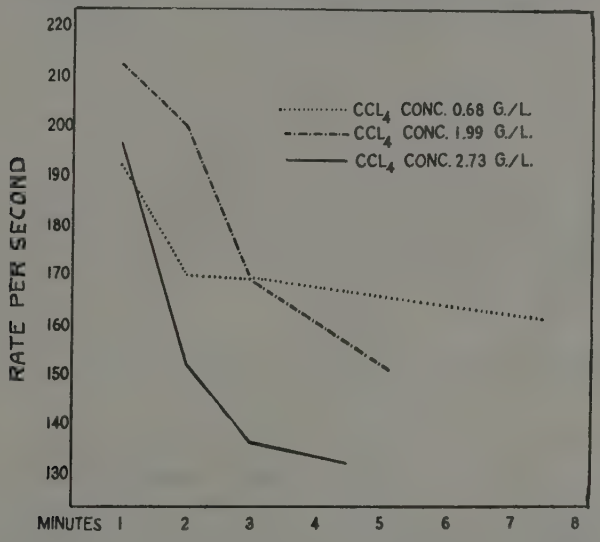

Fig. 3 : Effect of CCL_4 upon the rate of wing-beat of *Drosophila virilis.*

air passing through the columns of liquid carbon-tetrachloride. Occasionaly flies show a tendency of using only one wing in their flight inside the fumigation chamber while the other wing is either completely motionless or vibrating slightly in a very narrow angle.

This indicates to a great degree the inhibiting action of the fumigant upon the fight of the insect among many others effects (Figs. 2 and 3).

VII. EFFECT OF STARVATION UPON WING-BEAT FREQUENCY

Drosophila adults were kept under starvation for 48 hours before being tested to measure their wing-beat frequency. Samples of these were chosen at random and mounted in the flight chamber. These insects do not fly readily when stimulated by dropping suddenly the supporting platform from under their feet. By continuously trying, the author was able to record the wing-rate for these flies. These insects are not able to keep flying except for a few seconds and within a very low range of wing-rate. On causing a current of air to pass through the flight chamber it is clearly shown that

this factor induces a considerable increase in the wing-beat frequency of the insect (Fig. 4, and Table I).

In order to study the effect of the toxic fumes upon the wing-rate of starved insects, the author subjected some of these flies, which were left to starve for 48 hours, to the same concentration of toxic carbon-tetrachloride

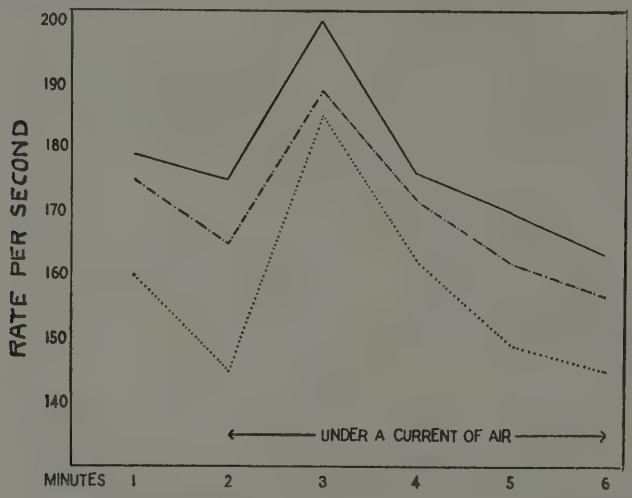

Fig. 4 : Wing-beat frequency of flies after a starvation period of 48 hours.

TABLE I

Wing-rate of starved Drosophila virilis *for* 48 *hours*

RATE OF WING-BEAT			RATE UNDER CURRENT OF AIR (0,27 mile per hour)				
First reading		Second reading	First reading		Second reading		
160	to	145	185	to	165	to	149
175	»	165	189	»	172	»	162
168	»	160	190	»	175	»	165
179	»	175	195	»	165	»	169
175	»	175	200	»	175	»	170

fumes. Several of these flies collapsed and were stupefied in the fumigation chamber even before they could show any sign of wing movement. A few succeeded in recording a very low rate of wing-beat. Apparently the effect of starvation is added to the toxic action of the fumigant in causing this very low rate of wing-beat (Table II).

TABLE II

Effect of CCL_4 upon starving Drosophila virilis

WING-RATE OF NORMALLY STARVING FLIES	WING-RATE UNDER EFFECT OF CCL4 (concentration 0.68 gram per liter)
167 to 170	142 to 140
181 » 175	156 » 150
162 » 159	143 » 149
183 » 180	160 » 159
175 » 169	139 « 142

These tests show clearly that starved insects are much more affected by the toxic action of CCL_4 and their resistance is decreased to a minimum as almost none of these starving insects were able to recover after passing the stupefaction period.

VIII. EFFECT OF CCL_4 UPON RATE OF WING-BEAT AT CONTINUOUS FLIGHT

Individuals of *D. virilis* were allowed to fly separately in the fumigating chamber for a period of 10 minutes continuously. After taking readings of their particular wing-rate at intervals of one minute, carbon-tetrachloride fumes are allowed to pass through the flight chamber at a known low concentration of 0.07 gram per liter. Table III shows the readings taken of wing-rate.

TABLE III

Wing-beat of continuous flight in Drosophila virilis *under low concentration of CCL_4 (0.07 gram per liter)*

NORMAL WING-BEAT	RATE AT CONTINUOUS FLIGHT								Rate after introduction of fumigant
	1 minute later	2 minutes later	3 minutes later	4 minutes later	5 minutes later	7 minutes later	9 minutes later	10 minutes later	
212	210	210	200	196	195	180	177	169	170-159
199	200	195	185	181	178	171	165	162	175-160
220	212	205	195	191	188	180	175	170	188-172
212	205	197	188	182	179	165	162	159	185-172
230	212	203	195	190	192	182	172	170	192-169

The flies under test showed a considerable decrease in their rate of wing-beat primarily as the result of fatigue ; yet as soon as toxic fumes were allowed to go through the fumigating chamber the wings record a slight increase apparently due to the shock of the CCL_4 upon the insect. This, however, did not last, as the insect soon stopped. Soon after, the flies col-

lapsed in a more or less rigid form of stupefaction. Some of these were able to recover and fly again for a few strokes ; yet again they stopped completely, taking a peculiar rigid shape with both wings stretched up, down, or one up and the other down.

IX. CONCLUSIONS

Various factors have been shown to cause certain fluctuations in the rate of wing-beat of insects. Under normal conditions adult flies of *Drosophila virilis* fly within a certain range of wing-beat frequency and a change in the environment affects the rate of wing-beat.

Experiments conducted to test the effect of carbon-tetrachloride upon the wing-beat frequency of *Drosophila virilis,* showed the inhibiting action of the fumigant upon the activity of the wings. The existance of carbon-tetrachloride fumes in the atmosphere of the fly tends to decrease the rate of wing-beat considerably. This decline in the rate corresponds with the increase in the concentration of the fumigant during the fumigation period.

Judging from the observations that some flies use only one wing for flight when under the effect of the fumigant, one might suggest that both wings are not innervated by the same part in the nerve ganglion, since one wing would be in full action while the other is considerably inhibited and vibrating at a low rate. This is supported by the experiments of Pringle (1949). He concluded that the frequency of contractions of the muscles is not determined centrally in the ganglion. Pringle (1939) also found that some muscles consisted of two parts, each having its own innervation.

The inhibiting action of the fumigant here is more clearly noted upon stowing insects as they record considerably lower rates of wing-beat.

Results of other experiments show that the inhibiting action of carbon-tetrachloride has an after effect upon the activity of the flies as the apparantly totally recovered flies show a clear drop in their rate of wing-beat.

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Origin and development of the reproductive system in insects

(with 4 Text-Figures)

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CONTENTS

I. Introduction. — II. The gonads of insects. — III. The genital appendages. — IV. The efferent ducts and accessory organs of the reproductive system in insects. — V. Summary. — VI. Bibliography.

I. INTRODUCTION

A great deal of work has been done on the anatomy and morphology of the reproductive system in insects. The greater part of this work deals with the completed organs. Ontogenetic studies on these parts in the successive stages are comparatively few. This fact, coupled with the obscurity which so often attends the initial growth phases, has caused a great discrepancy among authors' views with respect to the origin and development of the reproductive organs in insects. Although the works of Heymons (1892), Hegner (1915), Christophers (1922), Singh-Pruthi (1924, 1925), George (1928), Metcalf (1932), Mehta (1933), D'Rozario (1942) and others have advanced our knowledge about the development aspects of the subject, more efforts need to be made to incorporate the already existing ideas into one story, so that the subject becomes intelligible to those who seek to understand the nature of these parts.

In the course of a study of the reproductive system of Nematocerous flies from the development point of view (Abul-Nasr, 1950), the author became acquainted with similar studies on insects of different orders. As a result of this study he was convinced that what appeared at first to be controversial opinions could be brought together as parts of an harmonious whole. This paper is meant to be a contribution towards that end ; i.e., an attempt to co-ordinate opinions which were expressed by different authors and to prove that they are consistent with the story of ontogony.

The accompanying bibliography includes only those references which deal with the subject from the point of view of origin and development.

II. THE GONADS OF INSECTS

There are two principal theories as to the origin of the germ cells of insects' gonads : either that the germ cells do not relate to certain germinal layer, or that they belong to the mesodermal layer. This uncertainty of origin is due to the fact that differentiation of germ cells from the rest of the somatic cells cannot always be demonstrated at a special time of embryonic development in all species. In some insects, the germ cells are differentiated at the time of cleavage, when they migrate towards the posterior pole of the egg, passing through the protoplasmic substance of the «oosome ». According to Johannsen and Butt (1941), this takes place even before the primary epithelium of the embryo is completed — consequently, before the determination of the three germinal layers. This early differentiation becomes quite impossible in the case of some other species. According to Snodgrass (1936), who followed the works of Heymons (1892) and Hegner (1915), visible differences between the germ cells and the somatic cells appear, in most insects, only after the formation of the germ layers of the embryo, when the germ cells are found imbedded in the splanchnic layer of the abdominal mesoderm. The rudiments of the gonads appear as thickenings of the mesoderm, known as the genital ridges. These latter congregate in a varying number of coelomic sacs in the abdomen.

In agreement with Gustafson (1950), the only general assumption held by all embryologists at present is that the germ cells are differentiated in the early stages of cleavage and then migrate forward and occupy the mesodermal tissue of certain abdominal segments. Beyond this point we cannot obtain such general agreement.

In the female gonad the germ cells are differentiated posterior to the germarium area into smaller central follicular cells and larger peripheral oogonial cells. With the present technique of section cutting and staining, it is nearly impossible to draw any distinction between those cells which will turn into follicular cells and those which will become oogonial cells. All that we can say is that all the germ cells in the germarium area look the same at the beginning, and later factors such as nutrition, secretion, oxygen supply received from the haemocoele through the gonadial investment, may decide their fate. Also, the factor which is responsible for the differentiation of the oocyte from the rest of the oogonial cells is not yet determined. The yolk formation inside the oocyte is initiated by the dispersal of its nucleolar substance inside the oocyte cytoplasm. Each oogonium is surrounded by an envelope of follicular epithelium (egg follicle) which provides nourishment

to the growing oocyte while its cells are still succulent. In the case of a multi-cellular oogonium, the follicular epithelium envelope surrounds the whole group of oogonial cells, and the oocyte, in that case, grows mostly at the expense of the rest of the oogonial cells, which are thus called « nutritive or nurse cells ».

In the male, the germ cells inside each gonad do not differ from each other throughout their development, as all of them are involved in the same operation, which ends with transformation into spermatozoa. A very few male germ cells may fail to accomplish their transformation, and so they appear inside the testis as small, round, degenerate cells intermingled among the proper spermatozoa.

The gonadial investment is considered by most recent authors to be derived from the inner wall of the embryonic coelome sacs of the abdominal segments, i.e., the splanchnic mesoderm. When these coelomic sacs join together, their splanchnic wall encloses the two groups of the germ cells, forming of each a packed solid mass, which is the origin of the gonad. At the two ends of each gonad, the splanchnic tissue is continued anteriorly into the terminal filament and posteriorly into the mesodermal genital duct. In most cases, the gonadial investment is carried over to the post-embryonic stages as a thin peritoneal membrane in which cellular appearance is hardly detectable and which becomes thinner in response to the expansion of the growing gonad. This peritoneal membrane may acquire a secondary cellular appearance by the attachment of cells to its surface (author). In this case, the thin peritoneal membrane plays the part of a basement membrane, receiving the attached cells either externally from the fat cells or internally from some of the original undifferentiated germ cells.

III. THE GENITAL APPENDAGES IN INSECTS

The genital appendages in insects are structures of special importance to the morphologist, as well as to the systematist, because they are so often used as the last resort to differentiate between species when other characteristics fail.

It is now a well accepted view to consider the genital appendages in insects as homologous to the podial appendages of the thorax. It is also accepted by most recent authors that these appendages, in the female, belong to the eigth and ninth abdominal segments and, in the male, to the ninth segment only. The appendages on the ninth segment, in both sexes, are homologous and correspond to the coxopodites and endites of a complete arthropodan limb.

In the female (Fig. 1), the endites or gonopophyses of the appendages on the ninth abdominal segment become the second (inner or lateral) pair of

the ovipositor valves, and the coxopodites become the third (posterior or dorsal) pair.

The discrepancies in view, among recent authors, chiefly relate to the nature of the first (anterior or ventral) pair of ovipositor valves which arise on the eigth abdominal sternum. This first pair of valves is considered by some (Kershaw and Muir (1922) and Nel (1929) to be the coxopodites of the eigth sternum which fail to produce endites (true gonapophyses). Other authors, including Snodgrass, refer to the first pair of valves as the

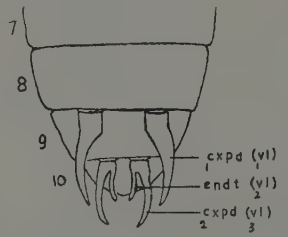

Fig. 1 : The genital appendages in the female insect, diagrammatic (*cxpd.*, coxopodite ; *enpd.*, endopodite ; *vl.*, valve ; arabic numbers refer to successive abdominal sterna).

gonopophyses of the eighth coxosternum. In Orthoptera, Snodgrass (1931) has shown that the coxopodites of the eigth sternum may exist in an atrophied state at the base of the first pair of ovipositor valves forming the anterior valvifers. Michener (1944) supports Snodgrass's view for Orthopteroid insects, but claims that in other insects ovipositor valves seem to develop from the coxopodites of the eigth sternum.

In the male (Fig. 2), the coxopodites of the ninth abdominal sternum become the gonocoxite, which may or may not be constructed off into the telopodites (the styles), and the endites, which turn into the true gonopophyses or paramere lobes. In some cases, the gonocoxites may sink or amalgamate in different degrees with the ninth sternite so that this sclerite in the adult should represent a coxosternum. In the latter case, the styles, if they are present, arise from the coxosternum without being carried by the coxites (Snodgrass). In other words, the claspers of the male genitalia may be formed by the gonocoxites alone, or by the gonocoxites provided with styles, or by the styles alone.

The paramere lobes may or may not divide secondarily. In case the paramere lobes do not divide, they may approach medially to enclose the intromittent organ and form its external sheath, which is called the aedeagophore (Fig. 2A, Pruthi 1925). If the undivided paramere lobes do not approach medially and do not coalesce, then they form what is called paramerophores (Fig. 2B, Abul-Nasr). But if the paramere lobes divide

secondarily, the result is a median pair of penis valves and a lateral pair of parameres, the first pair forming the appendicular intromittent organ sheath (the true aedeagus) and the second pair forming the true parameres (Fig. 2C). This latter case was shown to take place in Coleoptera, where the coxal lobes disappear in the immature stage and only the paramere lobes persist in the adult (Pruthi and Metcalf).

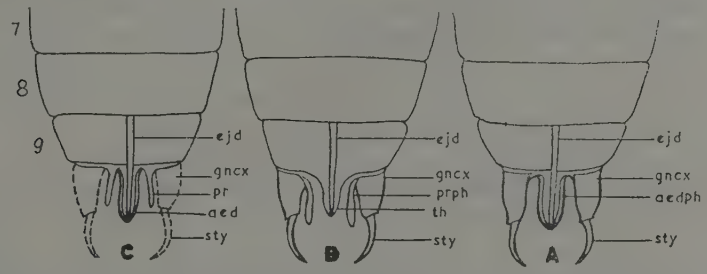

Fig. 2 : The genital appendages in the male insect, diagrammatic : (A) In Homoptera (Pruthi) and in Lepidoptera (Mehta) ; (B) In the more generalized insects (Snodgrass) and in some Diptera (Abul-Nasr) ; (C) In Coleoptera (Metcalf and Pruthi). — *aed.*, aedeagus ; *aedph.*, aedeagophore ; *ejd.*, ejaculatory duct ; *gncx.*, gonocoxite ; *pr.*, paramere ; *prph.*, paramerophore ; *sty.*, style ; *th.*, theca).

The question as to whether the coxopodites and endites (the coxal lobes and paramere lobes of Pruthi) arise from one pair which divides secondarily or whether they develop separately, is a matter which depends on the size of the coxal lobes. When these are large enough, th paramere lobes seem to develop on their inner base, but when the coxal lobes are small, the two pairs develop separately (author). It is essential to realise that the coxal lobes are the principal parts which give off the paramere lobes and so they should appear first. The intromittent organ outer wall may also be formed out of a segmental evagination behind the ninth sternum, carrying the gonopore on top of its elevation. This sort of structure is the theca of Weschè (1906), and it is usually found in the more generalised insects, but also may be preserved in some of the specialised froms (Fig. 2B). A part of the theca may be tucked inside the intromittent organ tube forming the eversible endotheca or preputial sac (Snodgrass 1936). Both theca and endotheca may be thickened in some parts to produce thecal plates. Thus it is of great importance to distinguish between the theca and thecal plates, which are of segmental nature, and the aedeagus and aedeagophore, which are of appendicular origin. In primitive insects, the theca may be found alone, but in more specialised forms, it is usually provided with thecal plates. When the appendicular sheath comes into existence, it replaces the theca and its plates, enclosing the intromittent organ by the paramere lobes or by the penis valves

which coalesce into a tubular structure. In some flies the penis valves, as well as the theca and thecal plates, are all present. In this case, the penis valves do not take over the original function of the theca, but they obsolesce, having almost no effective part in the protection of the intromittent organ. This state of affairs, I believe, is not merely a reçapitulation of a primitive character, but has a more significant meaning in the evolution of the intromittent organ. It suggests that the segmental theca, which formed the outer wall of the intromittent organ at the beginning of the evoluion of this organ, has proved to be more effective than the appendicular sheath. And so the theca is taking up its original function in some flies, of the penis valves are becoming restricted to performing a sensory function.

IV. THE EFFERENT DUCTS AND ACCESSORY ORGANS OF THE REPRODUCTIVE SYSTEM IN INSECTS

The trend of thought among recent workers is to consider that, in both sexes of insects, all the accessory organs of the reproductive system (accessory glands and spermathecae in the female and accessory glands and vesiculae seminales in the male) and most of the genital efferent ducts (except perhaps the proximal portions of the oviducts and vasa deferentia) develop from the hypoderm. The evolution of these parts in different insects is closely connected with the question of the location of the gonopore in the male and the female. The gonopore has always been considered, except in Collembola and Protura, to lie behind the ninth abdominal sternum in the male. In the female, the position of the gonopore ranges from the posterior border of the seventh abdominal sternum to that of the ninth. This had led some workers (Pruthi (1924), George (1928), Nel (1929), and Metcalf (1932)) to put forward the theory that the female gonopore shifts posteriorly and to consider the extent of this shifting as a measure of the specialisation of the efferent system. According to this theory, the female gonopore should lie, in the primitive insects, behind the seventh abdominal sternum. In the more specialised insects the gonopore has moved backwards to lie behind the eighth sternum. In the most specialised forms, the gonopore has continued its posterior shifting until it has reached the posterior border of the ninth abdominal sternum.

This theory of the posterior shifting of the female gonopore is in contradiction to Snodgrass's theory of the mesodermal gonoducts branching. According to this latter theory, the mesodermal ducts of the gonads opened, in the phylogenetic history of insects, in both sexes, at the bases of the appendages of the tenth abdominal segment and that, later, these ducts in the female developd branches to the seventh appendages and lost the original connection with the tenth appendages. The only substantial support

for Snodgrass's theory of branching was the discovery of Heymons (1912) in *Forficula*. This latter worker gave evidence of a primary branching of the gonoducts in *Forficula*, in both sexes, extending from the gonads to both the seventh and tenth segments. The study of *Chironomus* (Abul-Nasr, 1950) has shown that branching of the mesodermal gonoducts of the gonads does exist in both sexes, viz. a branch goes to the seventh abdominal segment and the other to the ninth segment. The persistent branch is the short one, in the case of the female, and the long one in the case of the male. Therefore, the condition in *Chironomus* gives fresh support to the branching theory of Snodgrass.

The two theories, the posterior shifting of the female gonopore and the branching of the mesodermal gonoducts can, however, be harmonised. In Onychophora and Chilopoda, which are often considered to be the ancestors of insects, and in Protura, which are considered by some to be the most primitive insects, the gonopores in both sexes are subterminal. In these creatures there are no real accessory organs (accessory glands and spermathecae) attached to the reproductive system. When such structures became necessary, the first step to be taken, presumably, was to push the female gonopore a little forward to give space for the new organs to develop posterior to the gonopore. This, according to Snodgrass's theory, would be accomplished by the branching of the mesodermal gonoducts to give off short

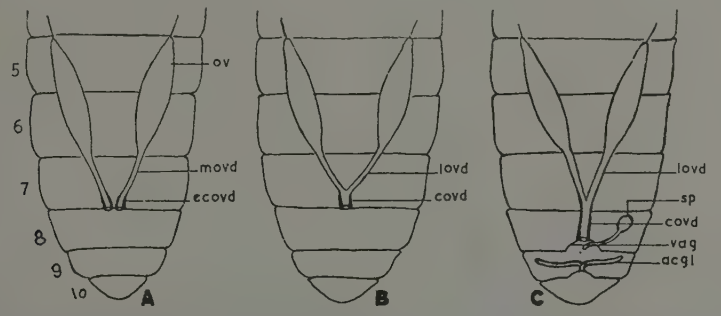

Fig. 3 : Successive stages in the evolution of the efferent genital system in insects, diagrammatic : (A) In Ephemeroptera ; (B) In Dermaptera ; (C) In Thysanura, Orthoptera, Isoptera, Hemiptera and Hymenoptera. — (*acgl.*, accessory glands ; *covd.*, common oviduct ; *ecovd.*, ectodermal oviduct ; *lovd.*, lateral oviduct ; *movd.*, mesodermal oviduct ; *ov.*, ovary ; *sp.*, spermatheca ; *vag.*, vagina).

branches which end on the seventh abdominal segment. At the posterior border of the seventh abdominal sternum arise two hypodermal invaginations to form two short ectodermal oviducts which link the mesodermal oviducts with the body wall through a double gonopore. This primitive case of the female efferent system exists in the present Ephemeropetra, where there is

still no sign of any accessory organs (Fig. 3A). Soon the double ectodermal oviducts coalesce into one common oviduct with a single gonopore behind the seventh abdominal sternum. This slightly advanced step is seen in present-day Dermaptera, where the accessory organs are found in a very rudimentary state (Fig. 3B).

Finally, the time came for fully developed accessory organs to appear. The spermatheca developed as a double invagination behind the eigth abdominal sternum and the accessory glands as another double invagination behind the ninth sternum. The appearance of the accessory organs was then accompanied by a posterior shifting of the female gonopore. The ventral position of the female gonopore did not suit either copulation or oviposition. The rudiment of the common oviduct continued to develop at the posterior border of the seventh sternum in the early stage, but moved to the posterior border of the eighth sternum through a hypodermal groove which later transformed into a tubular structure (Christophers 1922, and George 1928). Later, the rudiment of the common oviduct was carrried over entirely to the eigth abdominal sternum where it appears very close to, but quite separate from, the spermathecal rudiment (Pruthi 1925, and Metcalf 1932). In the last two cases, the vulvar opening lies at the posterior border of the eigth abdominal sternum and slightly in front of the spermathecal opening, and in most cases the two openings are enclosed inside the vestibule of the vagina, which is a short segmental inflexion (Fig. 3C). The last stage

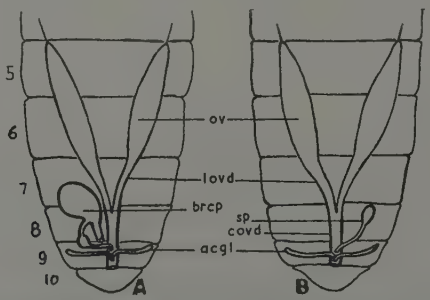

Fig. 4 : Efferent genital system in insects with the gonopore behind the ninth sternum : (A) In Lepidoptera ; (B) In Coleoptera. — (*brcp.*, bursa copulatrix ; other abbreviations as in Figure 3).

of the posterior shifting of the female gonopore is attained in most Lepidoptera (Fig. 4A) and Coleoptera (Fig. 4B) and may be present also in some Diptera (Metcalf 1933) and Hemiptera (Snodgrass 1933), where the gonopore lies behind the ninth abdominal sternum. In this case, the rudiment of the spermatheca has migrated posteriorly to share the rudiment of the accessory glands, which lies at the posterior border of the ninth sternum.

Thus, the original rudiment of the accessory glands besides giving rise to the accessory glands and the spermatheca, provides for the distal extension of the common oviduct which joins its proximal part developed from the rudiment behind the eighth strenum.

The male efferent system is much simpler than that of the female, one reason being that the provision of the male reproductive system with accessory organs (accessory glands and vesiculae seminales) eliminates the necessity for separate structures with separate openings. The risk of mixing the different products of these organs does not exist in the case of the male. So the provision of the male reproductive system with necessary accessory organs only required some specialization along the course of the ejaculatory duct. The only shift of the male gonopore took place very early, when it was carried from the subterminal tenth abdominal segment to the ninth segment, a consequence of the atrophy of the tenth segment. There is one rudiment on the ninth abdominal segment which gives rise to the double invaginations of the primitive ejaculatory ducts. In Ephemeroptera and Labiduroidea, where there are double penes, the openings at the apices of the penes are those of the primitive ejaculatory ducts. In other forms with a single penis a new secondary median invagination forms the penis tube which connects anteriorly with the ejaculatory duct and its distal opening serves as the functional gonopore (Pruthi 1925, Abul-Nasr 1950).

One thing about the efferent system in insects which still needs to be cleared up is the constitution of the paired gonoducts in both sexes.

At the end of the last century, Korschelt and Heider stated that the original mesodermal strands extending from the young insects gonads are not transformed along their whole length into the paired efferent ducts, but that their terminal portions degenerate and are replaced by newly formed portions which are derived from the proximal end of the ectodermal duct, when the two link together. This true statement has received consistent support by later works of Zandar (1900) in Hymenoptera, Muir (1918) in Coleoptera, Pruthi (1925) in Homoptera, Nel (1929) in Orthoptera and Dermaptera, Metcalf (1933) in Diptera, Abul-Nasr (1950) in Nemetocera. Metcalf's opinion is that a statement to the effect that the paired ducts of the efferent system are wholly mesodermal or wholly ectodermal in origin must be modified. The ducts appear to be partly mesodermal, derived from the original gonadial strands, and partly ectodermal in origin, the extent of each region varying with the species.

Nel has mentioned that the encroachment depends on a secondary replacement of the mesodermal epithelium by hypoderm during development, a process which is broadly analogous, perhaps, with the replacement of the midgut epithelium by ectoderm in higher insects (Mansour 1927, Tiegs

and Murray 1934). Alteration of tissues is most in accord with facts of regeneration, where a structure developed in the embryo from one germ layer may be regenerated from a different one.

V. SUMMARY

1. The gonads and part of the lateral gonoducts originate from the mesoderm, whereas the rest of the reproductive system develops from the ectoderm (hypoderm).

2. In the female, the primordial germ cells in the germarium have the potentiality to differentiate into follicular cells or oogonial cells after being, perhaps, stimulated by certain factors. In the male, all but a few of the primordial germ cells are transformed into spermatozoa.

3. The gonadial coat or the peritoneal membrane is mostly carried over to the post-embryo as a thin non-cellular structure. Fat cells from the outside or germ cells from the inside may adhere to the peritoneal membrane, using it as a basement membrane and giving it the appearance of a peritoneal epithelium.

4. The female ovipositor consists of three pairs of valves ; the first pair lie anterior and ventral, the second, inward and lateral, and the third, posterior and dorsal. The first pair of valves are considered to be, except perhaps in Orthopteroid insects, the extended gonocoxites of the eighth abdominal sternum ; the second pair to be the gonopophyses of the ninth sternum, and the third pair to be the extended gonocoxites of the latter sternum.

5. The male copulatory apparatus, which corresponds to the second and third pairs of ovipositor valves, arises from two pairs of lobes : the coxal lobes and the paramere lobes. The coxal lobes are usually constricted off into the stylus lobes and together they form the claspers or the forceps of the copulatory organ. The paramere lobes may approach medially and coalesce to form the aedeagophore or they may keep separate to form the paramerophores. The paramere lobes may divide secondarily to give rise to the lateral parameres and the median penis valves (the aedeagus).

6. In the female there are three independent and successive hypodermal invaginations : the common oviduct invagination which is, originally, behind the seventh abdominal sternum ; the spermathecal invagination behind the eigth abdominal sternum, and the accessory glands invagination behind the ninth.

In the male, the ejaculatory duct invagination lies, always, behind the ninth abdominal sternum.

7. The female gonopore moved from its original preterminal position across three segments and lies behind the seventh abdominal sternum. This

is explained by the genital mesodermal strands branching theory of Snodgrass and it is reasonable to imagine that this anterior move of the female gonopore was to give space behind the vulvar opening for the independent invaginations of the accessory organs. In recent insects, however, there is a tendancy towards a posterior shifting of the female gonopore to lie behind the eighth or ninth abdominal sternum, to amend the unsuitable ventral position of the female gonopore.

8. The male gonopore is established, in all insects, behind the ninth abdominal sternum, since it has left its original preterminal position because of the atrophy of the tenth abdominal segment.

9. The single gonopore is acquired in the female through the coalescence of the originally double common oviduct ; but in the male the gonopore is the opening of the penis tube, a secondary single invagination which appears behind the double ejaculatory duct invagination.

10. An inter-segmental inflection behind the gonopore forms the vagina in the female and the theca in the male.

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Neue oder bemerkenswerte Kleinschmetterlinge aus Syrien

[Microlepidoptera]

(mit 2 Abbildungen)

von Dr. H.G. Amsel (Buchenberg/Baden)

Herr A.S. Talhouk (Damascus) übergab mir bei seinem Besuch in Buchenberg im März 1953 eine Anzahl Microlepidopteren mit der Bitte um Determination. Ueber die Ergebnisse dieser Bestimmungen soll im folgenden berichtet werden. Es befinden sich unter den vorliegenden Stücken wiederum 2 neue Arten sowie einige recht bemerkenswerte, bisher wenig beobachtete Species.

Pyralidae

Nymphula affinialis Gn.

Damascus 28.8.1950. Die Art war aus Syrien bisher nur von Marasch bekannt gewesen. Sie kommt sonst in Persien, Mesopotamien, Palästina, Aegypten, Indien, Malakka, Sokotra und den Aru-Inseln vor.

Tortricidae

Oxypteron homsana sp. n. (Fig. 1).

Spannweite 19 mm. Vorderflügel bräunlich, bei 1/3 Innenrand ein etwas schräg stehender, dunkelbrauner Fleck, bis zur Falte reichend, hinter der Mitte der Costa einige unbedeutende, bräunliche Häkchen. Hinterflügel graubraun, Fransen heller, wie auf den Vorderflügeln. Wimpern der ♂ Fühler fast so lang wie der Fühler breit, Palpen vorgestreckt, letztes Glied sehr kurz.

Die neue Art ist fast zeichnungslos bräunlich. Lediglich der schmale Innenrandsfleck bei 1/3 fällt etwas auf. Er ist wenig scharf begrenzt, reicht bis zur Falte und besteht aus dunkelbraunen Schuppen. Die costalen Verdunkelungen hinter der Mitte der Costa sind sehr unbedeutend. Die Fransen sind ebenso hell wie auf den Hinterflügeln.

Das Vorderflügel-Geäder ist durch folgende Eigentümlichkeiten ausgezeichnet: *r*2 viel näher an *r*1 als an *r*3, *r*1 viel steiler als *r*2; *m*1 sehr

nahe an *r*5, *cu*2 auffallend weit von *cu*1, fast auf der Mitte der unteren Zellgrenze entspringend. In Hinterflügel sind *rr* und *m*1 kurz gestielt, *m*3 und *cu*1 deutlich getrennt.

Genitalapparat des ♂ : Innerand der Valven hinter der breiten Basis stark ausgehœhlt, dann mit einem langen, einem selhr kurzen und schliesslich einem mittelangen Dorn. Aedoeagus am Ende gespalten, in eine

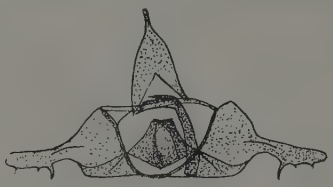

Fig. 1 : *Oxypteron homsana* sp. n. (Monotypus ♂, GU 2086, Homs/Syrien).

einfache scharfe Spitze auslaufend bzw. in eine verbreiterte, erheblich längere Lamelle, deren oberer Rand leicht gezackt ist. Fultura superior normal chitinisiert. GU. 2086.

Monotypus : 1 ♂ Homs (Syrien), 1.11.1952, leg. A. S. Talhouk.

Die neue Art gehœrt genitaliter in die unmittelbare Verwandtschaft von *O. eremica* Wlsm. Der Innenrand der Valve ist aber hinter der Basis viel tiefer eingebuchtet und der dann folgende Dorn viel grœsser. Bei *eremica* fehlen auch die dann folgenden beiden Dornen. Im Geäder des Vorderflügels sind auch erhebliche Unterschiede, da *r*2 viel näher an *r*1 ist. Bei *eremica* ist es grade umgekehrt, auch ist *eremica* mit 11-13 mm. Spannweite erheblich kleiner. Die Unterschiede gegenüber den anderen Arten der Gattung ergeben sich durch Vergleich mit den in meiner Revision der mediterranen *Tortricodes*-Arten gemachten Angaben (Siehe : *Bull. Soc. Fouad Ier Entom.*, XXXII, pp. 299-303, 1948).

Oxypteron palmoni Ams.

Der Ezzor (Oberlauf des Euphrat) 15.-18.11.1952. Die Art war bisher nur vom See Genezareth in Palästina bekannt, sie stellt eine interessante Bereicherung der syrischen Fauna dar.

Gelechiidae

Anarsia lineatella Z.

Damascus 25.10.1952. Die Art war bereits vom Libanon und Marasch bekannt.

Ethmia pusiella Romer

Mahara 3.11.1952.

Ethmia euphraticella sp. n. (Fig. 2).

Spannweite 28 mm. Kopf, Thorax, Schulterdecken und Halskragen zeichnungslos weiss. Vorderflügel weiss mit 1 schwarzem Punkt in der Falte bei 1/3, einem weiteren Punkt schräg nach aussen darüber in der Zelle und am Zellende. Hinterflügel hellgrau, seidigglänzend, Fransen weis. Hinterleib seidigglänzend, die ersten 4 Segmente überwiegend gelblich schimmernd, die letzten überwiegend grau. Beine grau, Palpen weiss, Fühler sehr kurz bewimpert.

Die neue Art kann in die Verwandtschaft von *tripunctella* Stgr. gestellt werden, mit der sie in der Zahl der schwarzen Punkte übereinstimmt *tripunctella* ist aber wesentlich kleiner und hat keine weisse, sondern eine seidiggraue Grundfarbe der Vorderflügel, auch ist die Stellung der Punkte zueinander abweichend. Mit allen übrigen der zahlreichen neu beschriebenen *Ethmia*-Arten besteht keine nähere Verwandtschaft.

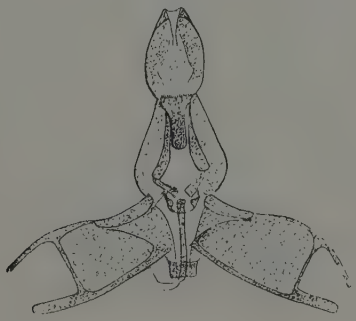

Fig. 2: *Ethmia euphraticella* sp. n. (Monotypus ♂, GU 2087, Der Ezzor (oberer Euphrat) Syrien.

Bei *euphraticella* ist der 2. Punkt viel näher am Faltenpunkt als am Zellschlusspunkt. Bei *tripunctella* ist der 2. Punkt von den beiden anderen annähernd gleich weit entfernt. Alle 3 Punkte haben die gleiche Grœsse. Die Vfgl-Grundfarbe ist rein weiss, ebenso weiss sind die Fransen aller Flügel, lediglich die Hinterflügel-Fransen sind am Analwinkel etwas grau-gelblich. Unterseits rind die Vlgl. grau, die Hfgl. eine Kleinigkeit heller, die Fransen sind auf beiden Flügelpaaren auch hier weiss. Palpen weiss, letztes Glied fast so lang wie das 2. Die Wimpern der Fühler sind etwas kürzer als der Fühler breit.

Genitalapparat des ♂: Uncusende leicht eingebuchtet. Gnathos nach oben zu verbreitert und hier sehr fein bestachelt. Valven in 2 annähernd gleichlange Arme ausgezogen, derjenige des Innenrandes ist etwas breiter. Aedoeagus kurz und stark gebogen, ohne Cornuti. GU. 2087.

Monotypus : 1 ♂ Der Ezzor (oberer Euphrat)/Syrien, 15.11.1952, leg A.S. Talhouk.

Tineidae

Tinea libanotica Ams. (*Bull. Soc. Sci. Nat. Maroc, XXX, p.* 178, 1950)

Ergänzend zu der l.c. angegebenen Originalbeschreibung kann jetzt auf Grund des Befundes zweier in Latakia am 11.5.1952 aufgefunder ♂ ♂ gesagt werden :

Kopf, Stirn, Thorax, Tegulae und Vorderflügel sind einfarbig intensiv ockerfarben, die Fransen sind kaum heller. Die Hinterflügel sind einfarbig dunkel, nur an der Costa wurzelwärts aufgehellt, die Fransen sind gelblich, aber nicht so intensiv ockerfarben wie die Vorderflügel, mit deutlicher, dunkler Basallinie. Die Fühler sind deutlich bewimpert, oberseits gelb und dunkel geringelt, die einzelnen Glieder sind gegeneinander abesetzt. Die Palpen sind oberseits gelblich, unterseits bräunlich, 3. Glied 1/3 so lang wie das 2., vorgestreckt, grade, insgesamt sind die Palpen doppelt so lang wie der Augendurchmesser. Maxillarpalpen 1/2 so lang wie die Labialpalpen, Rüssel sehr klein. Beine überwiegend gelblich, Hinterschienen oberseits und unterseits ziemlich lang behaart. Unterseits sind die Vorderflügel überwiegend gelblich, die Hinterflügel dunkel mit gelblichen Fransen.

Da die Art nunmehr auch aus dem Küstengebiet Syriens vorliegt, kann sie nicht als reines Gebirgstier angeschen werden.

Neue Pterophoriden, Gelechiiden und Tineiden aus Palästina und Malta

[Microlepidoptera]
(mit 8 Abbildungen)

von Dr. H. G. Amsel, Buchenberg / Baden

Pterophoridae

Agdistis minima sp. n. (Fig. 1).

Spannweite 14 mm. Vorder- und Hinterflügel schwarzgrau, zeichnungslos. Fühler des ♂ ungeringelt, relativ dick und lang, bis zur Flügelspitze reichend.

Genitalapparat des ♂: Uncus mit zwei weit auseinander stehenden parallelrandigen ♂ Zipfeln. Beide Valven einander sehr ähnlich, aber nicht ganz symmetrisch, ohne Ausbildung eines Costalarmes. Aedoeagus stark gebogen. 9. Sternit mit zwei gleichlangen Zipfeln. GU. 254.

Holotypus: 1 ♂ Tel-Aviv (Palästina) auf der Düne am 24.7.1930 von Herrn W. Einsler gefangen.

Allotypus: 1 ♀ Vom gleichen Fundort, Datum und Biotop.

Beide Exemplare sind stark gelflogen. Es ist bei dem schlechten Zustand der Stücke nicht ausgeschlossen, dass späterhin tadellos erhaltene Exemplare

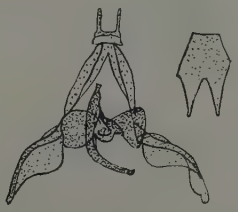

Fig. 1: *Agdistis minima* sp. n. (Holotypus, GU. 254, Tel-Aviv).

eine Zeichnung erkennen lassen werden, doch ist bei beiden Stücken auch da, wo die Schuppen noch einigermassen erhalten geblieben sind, nicht die Spur einer Zeichnung zu sehen. Das ♂ ist durch die relativ dicken und langen Fühler auffallend, das ♀, das ich wegen der übereinstimmenden Grœsse und wegen des gleichen Fundortes und Biotopes als hierher behœrig ansehe, hat wesentlich dünnere und kürzere Fühler. Sie reichen nur bis 3/4 der Costa.

Die Art ist wegen ihrer Kleinheit mit keiner anderen bisher beshriebenen zu verwechseln. Die in der Grœsse am nächsten kommende, nach einem einzi-

gen Exemplar aus der Cirenaica beschriebene Art *nanus* Tur. 1924 (*Atti Soc. Ital. Sc. Natur.*, LXIII, p. 150, Taf. IV, Fig. 39), hat eine Spannweite von 15.5 mm. und ist durch den stark verdunkelten Analwinkel der Hinterflügel sehr ausgezeichnet.

Agdistis melitensis sp. n. (Fig. 2).

Spannweite 14-15 mm. Vorderflügel grau, Innenrand nur wenig heller, Costa aufgehellt, bis zur Mitte grau, dann mit 3 bzw. 4 hellen und 3 dazwischenliegenden Längsfleckchen. Am Beginn der Zelle, an der unteren Zellecke und auf der Mitte der unteren Zellbegrenzungsader ein dunkler Fleck. Der mittlere Fleck von den beiden anderen in gleicher Entfernung. Fransen von Vorder und Hinterflügel heller grau. Hinterflügel einfarbig grau, Analwinkel kaum dunkler. Fühler kaum geringelt, Palpen grau.

Genitalapparat des ♂: Uncus zweiteilig, oberer Rand dieser Teile stark gewellt, die Enden kurz hakenförmig. Valven mit langen Costalarmen, die bis zum Ende der Valven reichen. Beide Arme sind annähernd symmetrisch, sehr schmal, die Enden abgerundet und unmerklich erweitert. Die rechte Valve ist annähernd parallelrandig, das Ende abgerundet. Eine

Fig. 2: *Agdistis melitensis* sp. n. (Paratypus, GU. 1566, Malta): Uncus in Lateral-Ansicht.

von der Basis ausgehende, zunächst breite Verstärkungsleiste, verschmälert sich bis zur Mitte des Innenrandes und läuft dann als feiner Strich bis zum Ende der Valve, wo sie als feines, kleines, annähernd dreieckiges Plättchen über den Valvenrand hinausragt. Die linke Valve ist ganz abweichend: Die Costa ist grade, der Innenrand stark gewellt. Das Vinculum ist gross und fast dreieckig mit deutlicher Mittellinie. Aedoeagus sehr eigenartig: ein bei 1/5 beginnende, kräftige Chitinspange reicht bis 1/2 und wird unten und oben von einer scharfen Spitze begrenzt. Die obere Spitze ist länger als die basal gelegene und reicht über den Rand des Aedoeagus hinaus, während die basale grade bis zum Rand geht. Der Aedoeagus ist insgesamt stabförmig, so

lang wie die Valve, das Ende ist zunächst etwas erweitert und dann zugespitzt. 9. Sternit mit zwei ungleich langen Zipfeln. GU. 1566.

Der Genitalapparat ist von den bei Herbulot (*Lambillionea*, L, Nr. 1/2, pp. 16-19, 1950) und bei Pierce und Metcalf (Genitalia of the Pyrales, Deltoids und Plumes, Taf. XXIX, 1938) abgebildeten Armaturen vollkommen verschieden. Hier werden die Arten *meridionalis* Z., *bennetti* Cur., *tamaricis* Z., *sphinx* Wlsm., *adactyla* Hb., *heydenii* Z., *frankeniae* Z., *paralia* Z., *staticis* Mill., *ingens* Chr. und *satanas* Mill. dargestellt. Ganz abweichend sind auch *tyrrhenica* Ams. und *pseudosatanas* Ams.

Von den genitaliter noch nicht untersuchten Arten ist *salsolae* Wlsm. durch viel kräftigere, schwarze Flecke und vor allem durch den schwarzen Strich längs des Innenwinkels ganz abweichend. Ein ♀ von *salsolae* (Paratypus) liegt mir vor. *canariensis* Rbl. ist mir unbekannt, dürfte aber als endemische Art der Canarischen Inseln hier nicht in Betracht kommen. Die Arten *lutescens* Tur. 1927 (Spannweite 27 mm.), *gigas* Tur. 1924 (Spannweite 31 mm.), *excurata* Meyr. 1921 (Spannweite 22 mm.) kommen wegen ihrer bedeutenden Grœsse zum Vergleich nicht in Frage. Lediglich *nanus* Tur. 1924 ist ebenso wie die vorstehend beschriebene *minima* Ams. mit einer Spannweite von nur 15,5 mm. vergleichbar. Sie hat aber viel lebhafter gezeichnete Vorderflügel und den charakteristisch verdunkelten Analwinkel der Hinterflügel.

Holotypus: 1 ♂ Malta, Salina, Sommer 1950 (Coll. Delucca).

Allotypus: 1 ♀ Malta, Salina, Sommer 1950 (Coll. Delucca).

Paratypen: 2 ♂♂, 3 ♀♀ vom gleichen Fundort 1.7.1949; 23. 9-21.10.1950 in Coll. Delucca und Amsel.

Gelechiidae

Symmoca melitensis sp. n. (Fig. 3).

Spannweite 15 mm. Vorderflügel weissgrau. Costa der Vorderflügel an der Wurzel mit einem dunklen Fleck, ein weiterer bei 1/3 und bei 3/4. Oberer und unterer Zellschlusspunkt deutlich. Weitere Flecke am Beginn der Zelle und in der Falte bei 1/2 sowie am Saum. Fühler ungeringelt. Palpenendglied so lang wie das Mittelglied.

Genitalapparat des ♂: Uncus tief eigenbuchtet, die beiden Zipfel unbedornt. Costalarm der Valve sehr lang, bis 3/4 bzw. 4/5 der Valvenlänge reichend. Costa der Valve gleichmässig und sehr schwach gebogen. Sacculus am Ende rechtwinklig zur Costa umgebogen und die Costa deutlich überragend. Aedoeagus halb so lang wie die Valve mit zwei Feldern feiner Cornuti. GU. 1854.

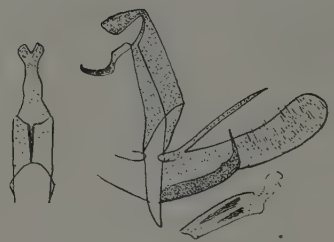

Fig. 3: *Symmoca melitensis* sp. n. (Paratypus, GU. 1854, Malta). Links Uncus, Gnathos und Tegumen in Ventral-Ansicht.

Holotypus: 1 ♂ Malta, Wieki, 16.6.1949, Coll. C. Delucca.
Paratypus: 1 ♂ Malta, Wieki, 16.6.1949, Coll. H. G. Amsel.
Beide Exemplare sind schlecht erhalten.

Die neue Art steht *signatella* HS. genitaliter am nächsten. Bei dieser ist jedoch der Uncus nur schwach eingebuchtet, die beiden Zipfel sind mit Dornen besetzt, die Costa der Valven ist nach aussen zu viel stärker gebogen und der Aedoeagus hat nur 1 Feld feiner Cornuti. (Vergl. Pierce und Metcalf, Genitalia of the Tineina, Taf. LXVII).

Megacraspedus lativalvellus sp. n. (Fig. 4).

Spannweite 13-15 mm. Vorderflügel gelb-bräunlich, zeichnungslos, die Adern leicht aufgehellt. Hinterflügel grau. Palpenendglied so lang wie das Mittelglied, letzteres lang abstehend behaart.

Die Art gehœrt äusserlich in die unmittelbare Nachbarschaft von *separatellus* (Fig. 5) und *dolosellus* Z. (Fig. 6) und ist von beiden ohne Genital-Untersuchung kaum sicher zu trennen. Besonders *separatellus* ist äusserlich so gut wie ganz übereinstimmend. Der Aussenrand der Hinterflügel ist bei dieser Art ebenso schräg wie bei *lativalvellus*, während er bei *dolosellus* deutlich steiler ist.

Fig. 4: *Megacraspedus lativalvellus* sp. n. (Paratypus, GU. 1850). — Fig. 5: *Megacraspedus separatellus* F. (GU. 1851. Ungarn). — Fig. 6: *Megacraspedus dolosellus* Z. (GU. 1882, Bœhmen).

Im Genitalapparat sind alle 3 Arten deutlich verschieden, und hier zeigt sich, dass *lativalvellus* von den beiden anderen genannten Arten ziemlich

entfernt steht. Der Gnathos ist relativ gross und hakenförmig als Viertelkreis gebogen, bei beiden anderen Arten ist er viel kleiner und lediglich unmittelbar hinter der Basis etwas gebogen, sonst grade. Die Valven sind an der Basis stark verbreitert, fast etwas kugelig aufgetrieben, bei den beiden anderen Arten nicht oder doch kaum verbreitert. Ueberdies reichen die Valven bei *lativalvellus* bis etwas über die Basis des Uncus, bei *separatellus* nur bis zur Basis des Gnathos und bei *dolosellus* nur bis zur Spitze des Gnathos. Das Vinculum ist bei *lativalvellus* ganz abweichend, indem der obere Rand (R) kreisförmig gebogen ist, während er bei ben beiden anderen Arten spitzwinklig eigebuchtet erscheint. Der Aedoeagus ist an der Basis kuglig, dann ganz grade, die beiden anderen Arten haben einen deutlich geschwungenen Aedoeagus. Der Uncus ist breiter und grœsser.

Mit *tutti* Wlsm. 1897 (*Ent. Rec.*, IX, p. 140), einer mausgrauen Art, besteht keine nähere Verwandtschft. Die Angaben über die mediterranen Verkommen von *separatellus*, der u.a. von Sizilien und Kreta gemeldet wurde, bedürfen dringend der Nachprüfung. Es ist durchaus mœglich, dass *lativalvellus* mit *separatellus* verwechselt wurde.

Holotypus: 1 ♂ Malta, Salina, 16.3.1952, leg. C. Delucca.

Paratypen: 2 ♂♂ Malta, Salina, 31.3.1952, leg. C. Delucca.

Der Holotypus und ein Paratypus befinden sich in der Coll. Delucca, der andere Paratypus in Coll. Amsel.

Tineidae

Praeacedes n. gen.

Von *Accdes* Hb. (Typus : *Tinea lapella* Hb.) im wesentlichen durch den tief gespaltenen Aedoeagus unterschieden. Uncus und Gnathos breit dreieckig und zugespitzt, Valven einfach, Vinculum (Saccus) lang stabförmig. Geäder ohne besondere Auszeichnungen, alle Adern frei aus der Zelle. Fühler des ♂ nackt, ziemlich dick, fast bis zur Flügelspitze reichend, die des ♀ dünner und kürzer.

Typus: *Praeacedes deluccae* sp. n.

Praeacedes deluccae sp. n. (Fig. 7).

Spannweite 9-12 mm. Vorderflügel-Grundfarbe gelblich kaum glänzend, mit dunkelbraunen Schuppen ziemlich gleichmässig bedeckt, am Zellende und in der Falte ein kaum erkennbarer diffuser Punkt. Hinterflügel grau. Kopfhaare bräunlich wie der Gesamteindruck der Vorderflügelfarbe. 2. Palpenglied mit einzelnen abstehenden Haarborsten, letztes Glied kaum kürzer als das zweite.

Die unscheinbare Art macht den Eindruck einer sehr dunklen *fusci-punctella* Hw., erinnert auch stark an *insectella F.* (= *misella Z.*) hat aber

mit beiden Arten genitaliter garnichts zu tun. Die Verdunkelung der Vorderflügel ist sehr gleichmässig, da der Zellschlusspunkt und der Fleck in der Falte kaum sichtbar sind. Die Fransen der Vorderflügel zeigen in der Mitte eine schwach entwickelte Teilungslinie, die der Hinterflügel sind ohne Auszeichnungen.

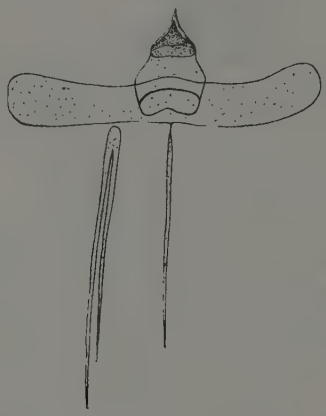

Fig. 7 : *Praeacedes deluccae* sp. n. (Paratypus, GU. 1562, Malta).

Der Genitalapparat des ♂ ist sehr charakteristisch durch den tief gespaltenen Aedoeagus. Die beiden Teile des Aedoeagus sind unterschieldlich lang. Gnathos und Uncus haben die gleiche dreieckige, zugespitzte Gestalt, doch ist der Gnathos etwas kleiner als der Uncus. Die Valven sind ohne jede Auszeichnungen, paralellrandig, nach dem Ende zu kaum erweitert. Das Vinculum ist sehr shmal stabförmig, etwas länger als die Valven lang sind. GU. 1562.

Holotypus: 1 ♂ Malta, Gharghur, 19.9.1951.

Allotypus: 1 ♀ Malta, Gharghur, 19.9.1951.

Paratypen: 4 ♂♂, 1 ♀ vom gleichen Fundort 28.8-19.9.1951.

Ich widme die neue Art Herrn Dr. Delucca, dem erfolgreichen Erforscher der Malta-Fauna, in dessen Sammlung sich die Typen mit Ausnahme zweier Paratypen befinden.

Unter dem Material der Malta-Ausbeute befanden sich auch noch zwei weitere Exemplare einer *Tinea*-Art, die durch Genital-Untersuchung als unsere gewœhnliche *fuscipunctella* Hw. identifiziert werden konnte. Das Präparat der Art aus Malta stimmt durchaus mit solchen von Stücken aus Berlin, Osterode (Harz) und Dalmatien überein. Ob aber diese *fuscipunctella*-Stücke mit der englischen *fuscipunctella* tatsächlich übereinstimmen, erscheint mehr als fraglich, wenn man die Beschreibung und Abbildung der

Art bei Pierce und Metcalf, Genitalia of the Tineina, p. 161, und Taf. 62 vergleicht. Im Text heisst es dort : « Gnathos paired, two ovate arms ». Bei allen von mir untersuchten Stücken ist dagegen der Gnathos ein schaufelförmiges Ganzes, also unpaar. Er reicht genau bis zur Spitze des Uncus, ist an den Rändern stark chitinisiert, sonst sehr schwach. Die

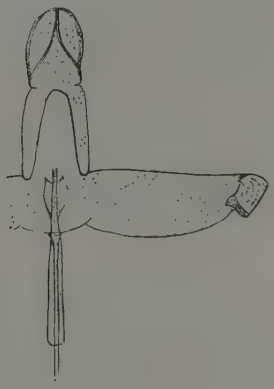

Fig. 8 : *Tinea spretella* S.V. (GU. 1565, Osterode/Harz).

Valven werden bei Pierce und Metcalf wesentlich breiter, viel stärker behaart und mit anders geformten Anhängseln am Ende gezeichnet. Es erscheint nicht sehr wahrscheinlich, dass diese Anhängsel lediglich einer anderen Lagerung der Armatur im Präparat ihre besondere Gestalt verdanken, obwohl dies nicht ganz von der Hand zu weisen ist. Man gewinnt daher den Eindruck, dass die englische *fuscipunctella* eine andere Art ist. Ich werde in dieser Auffassung auch durch die Abbildung der *fuscipunctella* bei Corbot und Tams (*Proc. Zool. Soc. London*, 113, Fig. 232) bestärkt, wo die Armatur in Lateral-Ansicht dargestellt wird und der Gnathos ebenfalls paarig gezeichnet wird.

Sollte sich meine Vermutung durch Untersuchung weiterer englischer Stücke bestätigen, so müsste für die deutschen und continentalen Stücke der alte Name *spretella* S.V. wieder aufgenommen werden (Fig. 8).

Observations on the biological races of *Stegobium paniceum* L.

[Coleoptera : Anobiidae]

(with 5 Tables, and 2 Text-Figures)

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I. INTRODUCTION

Stegobium paniceum L., was recorded by Wollaston (1864), Reitter (1911), and Kerrick (1921), as cosmopolitan (quoted from Janisch, 1923).

Howard (1900), Runner (1919) and others, stated that *Stegobium paniceum* L., is injurious to cured and uncured tobacco. Howard reports that there are several beetles which occasionally affect tobacco after the leaves are dried, in much the same manner as does the cigarette beetle *Lasioderma serricorne* Fabr. This author said : « The so-called drug-store beetle *Stegobium paniceum* L., an insect which feeds on enormous range of food, and occurs in drug-stores, whence its popular name, will also breed successfully in tobacco, although we cannot say that this substance is its preferred food ».

Back and Cotton (1940) have reported that *Stegobium paniceum* L., was among the pests of upholstered furniture and rugs and described the beetle as a very general feeder, attacking a great variety of stored-food and other material.

It is found as a pest of foodstuffs and other material in North America (Chittenden, 1902), South America (Gay, 1849), Canary Islands (Wollaston, 1864), Germany (Janisch, 1923, and Zacher, 1918), Spain, Japan, China, Australia, Venezuela, Italy, Egypt, India, Algeria and the Cape of Good Hope (see Janisch, 1923).

From the great variety of food and other material used by the beetles and attacked or eaten by *Stegobium*, we come to the conclusion that nothing except a minor degree of specialization has occurred in this species.

It has often been stated (Thorpe and Jones 1937) that insect species which breed on two or more hosts usually become split into biological races, each of which is attached to a particular food-plant or host as the case may be. But although the fact of the existence of biological races is well known, their mode of origin is, in most cases, in dispute. It is not known how far the biological characters of such races are genetically fixed, and it has been suggested that in many cases a group of individuals may become restricted to certain host species not by any genetical change, but by a kind of conditioning as a result of which the adult female is attracted and compelled to lay her eggs on the particular species on which she had fed as a larva. This is the idea behind the so-called « host-selection principle » of Wahlberg.

The olfactory conditions may influence the production of biological races, by the differentiation of species into groups of individuals each associated with a particular food. Thorpe and Jones (1937) have shown that such conditioning can actually occur and have stressed its possible importance as an isolating factor.

It is obvious that if a conditioning of this sort was actually occurring, a polyphagous insect species tend to become split into two or more populations each attached to a given species of host.

It is known, however, that the characters which distinguish biological races are in fact often germinally fixed, and in some instances it has been shown that even though all structural differences are absent there may be repugnance for cross-breeding between two biological races of the same species (Thorpe, 1930 b).

Experiments carried by Thorpe (1929), with the moth *Hyponomeuta padella*, indicate that this insect is divisible into two biological races which were formerly regarded as separate species, one race is specially attached to apple and the other to hawthorn and blackthorn.

Stegobium paniceum L., is a polyphagous insect and during the course of the experimental work on the biology of this insect, the author has discovered that the curious habit of this beetle of attacking a great variety of stored-food and other material was associated with the development of two biological strains or races with marked different rates of development. It is quite possible that there may be more than two biological races of this insect according to its habit of attacking a great variety of food.

The discovery of the two biological races of *Stegobium paniceum* L., is of considerable interest and is of great importance not only from the question of the origin of species, but also from the standpoint of applied entomology.

One race in Europe is specially attached to grain and its products as food to its larvae, the other race in the U.S.A. develops solely at the expense of cured and uncured tobacco. The imagines of the two forms are structurally identical, but exhibit differences in size, in colour and also in the cocoon texture and method of oviposition, as shown in Table I. For convenience the two forms of *Stegobium* are hereafter referred to as flour race and tobacco race.

The author was able to rear *Stegobium* in the laboratory without any difficulty upon various types of food (Azab, 1953) such as whole-meal flour, oat-meal flour, pea flour, ground yellow maize, ground polished rice and ground barley. But attempts were made by all possible means to rear the flour-reared individuals from the egg stage in tobacco resulted in failure and not even one larva hatched. Again hatched larvae reared in flour were also transferred to tobacco, but these either did not complete their transformation to the adult stage and did not survive long.

The author received a parcel containing sliced pipe tobacco from the U.S.A. in 1950 which was found infested with *Stegobium paniceum* L. and its larvae.

In this present study, attempts to breed the tobacco-reared insects in flour have resulted in failure and not even one female adult of the tobacco race laid eggs on flour but eggs could only be secured when the flour was either contaminated with the smell of tobacco or supplemented with ground tobacco. The author has discussed the host-selection principle very fully and tested it with reference to *Stegobium paniceum* L. It was found that in practically all the experimental studies, the adults of the two forms of *Stegobium* upon emergence exhibited a marked preference for egg-laying for the host species in which they had fed as larvae.

Similar results were obtained by Craighead (1922) during his experiments with about a dozen species of wood boring Cerambycid beetles. He found that, in all the species studied, the adults exhibited marked predilection for the host-species in which their larval existance was passed. He also found, that continued breeding appeared to intensify the preference and, in some species, transference to another species of host for only a year was said to be sufficient to determine a preference for this host by the resulting adult beetles.

The outcome of the host-preference is the evolution of special physiological strains, or races, each betraying its own particular host-preferences, but at the same time, exhibiting little or no indication of morphological differentiation. Such preferences become habituated and destined through heredity to result, in course of time, in increasing divergence and to lead ultimately to the formation of separate species.

The adult of *Stegobium paniceum* L., does not require food. This was

proved by Janisch (1923) and confirmed by the author. In the course of the experimental work, it was found, that the female adults of *Stegobium* appeared to be first attracted to the food used as an oviposition site by the sense of smell and when the females offered the choice of objects containing various kinds of food and other material to oviposite on, they laid all their eggs on the kind of food in which they had been reared as larvae. The attraction to the host species has been demonstrated experimentally in an olfactometer of the type described by Thorpe in 1937 and 1938.

From the data given in this paper, it became clear that the results obtained by the author lend strong support to Hopkin's theory (1916), which is now known as the « Host-selection principle ». According to this authority, in a given insect species that is capable of breeding in two or more host, individuals will normally continue to select the particular host species upon which their own life-cycle was passed.

II. BIOLOGICAL OBSERVATIONS ON THE TWO RACES OF STEGOBIUM PANICEUM L.

Observations on the biological race of *Stegobium paniceum* L. which is attached to grain and its products were previously fully made by the author

TABLE I

The differences exhibited by the two biological races of Stegobium paniceum L.

STAGES	FLOUR RACE	TOBACCO RACE
Egg	(1) On the whole ellipsoid, of milk-white colour and slightly opalescent.	Nearly oval, colour pale yellow, slightly flattened on the side towards the substrate.
	(2) Average size is 0.43 mm. long and 0.26 mm. broad.	Average size is 0.35 mm. long and 0.24 mm. broad.
	(3) Eggs laid in heaps closely packed in strings or sometime in the shape of a net.	Eggs laid singly, very rare in heaps.
Larva	(1) The fully grown larva is covered with white silky hair.	The fully grown larva is relatively smaller in size and covered with silky yellow hair.
	(2) The larva constructs a small cocoon and disappears within the confine of the cocoon. In floury material the cocoon is practically ellipsoid and is built from secretion and flour.	The construction of the cocoon is dependent on the kind and arrangement of tobacco. In tobacco leaves the larva lies freely and builds no cocoon, but in ground tobacco the larva cements two particles of tobacco and the cocoon is hollowed out in both particles.
Pupa	(1) Shining, white and very soft.	Semi-shining, yellowish white and not very soft.
	(2) Pupation always takes place inside a cocoon.	Most larvae pupate freely, very rarely pupate inside cocoons.
Adult	(1) Little more than one-tenth of an inch in length.	Less than one-tenth of an inch in length.
	(2) Reddish brown in colour.	Dark reddish brown in colour.

in 1942. When the other race of *Stegobium* which develops solely at the expense of tobacco was discovered, it was thought desirable to give a clear picture of the differences exhibited by the mature and immature stages of the two forms of *Stegobium,* as this is not only important from the biological point of view, but also might provide a useful knowledge. The imagines of both forms are structurally identical but as shown in Table I, they exhibit difference in size, in colour, in cocoon texture and in method of oviposition.

III. MATERIAL AND TECHNIQUE

Four cultures of flour-reared insects were obtained, each kept in two-pounds jam jar, and the beetles were reared continuously on whole-meal flour. The four cultures were kept at 25° C., and 70 % relative humidity. The flour before use, was sterilized and brought into equilibrium with the required humidities, and was first sifted to remove particles which would otherwise be retained with the eggs which were readily recovered by sifting through No. 1 B bolting silk cloth.

The tobacco-reared insects were bred solely either in tobacco leaves or in ground tobacco and each culture was kept in one-pound jam jar. The types of tobacco selected for the oviposition and developmental experiments were kept as constant as possible by always obtaining them from the same commercial source in order to bring about as uniform an original environment as possible. The kinds of tobacco used were either dried tobacco leaves (uncured) or ground tobacco obtained by grinding the former leaves and cigarette tobacco. The tobacco before use was brought into equilibrium with 75 % relative humidity. The cultures of tobacco-reared insects were kept at room temperature which fluctuated from 23 to 28° C., and 75 % relative humidity.

As the work progressed, it was thought desirable to provide a wider range of different cultures of *Stegobium* using the same set up for the experimental purposes. After nearly 50 days, it was found possible to obtain at any time several hundred adults at the same age bred from either whole-meal flour or tobacco.

Because of the great resemblance of the external characters of the male and the female adults of *Stegobium paniceum* L. and the sexing of the adult insects without damaging them, the insects were removed carefully from the cultures in the pupal stages, as in this, the only reliable external sexual characteristic for any stage is found.

When the ventral posterior ends of the male and the female pupae are examined under low magnification, this sexual distinction is obvious. On the terminal segment, the female has a pair of small rudimentary appendages which are reduced to indistinct elevations in the male. These so-called ap-

pendages are the rudiments of the female and male genitalia. This distinction between the two sexes is shown in Figure 1.

The removal of the pupae from these cultures not only simplifies the determination of sex, but also, enables one to make an exact recording of the age of the specimens.

Fig. 1 : A diagram of the posterior end of the male and the female pupae of *Stegobium paniceum* L., showing the sexual character.

In tobacco leaves cultures, the lavae pupated normally and freely, but in ground tobacco cultures the larvae constructed cocoons and it was possibly easy to extract the pupae from their cells in an undamaged condition by the help of a small scoop, two forceps and a soft brush. These pupal cells constructed of ground tobacco were softer to break up than those constructed of whole-meal flour, the latter were as hard as cement.

The pupae after being removed carefully from the cultures and sexed, were put separately in a small jars or shallow petri dishes on a filter paper and were kept under the same condition of temperature and humidity, until the adults were emerged. The newly emerged adults of closely similar age were used for the experimental insects. Glass tubes of 2×1 inch covered with muslin held in position by rubber bands were used.

Temperature and relative humidity at which the experiments were conducted will be stated at the beginning of each experiment.

IV. THE CHOICE OF OVIPOSITION SITE

The majority of beetles appear to require food as adults. Some short-lived species such as *Bruchus chinensis, Lasioderma serricorne, Anthrenus verbasci, Trogoderma granaria* and many others, however, have when been newly emerged reserves of fat and are able to complete their adult life and lay their normal number of eggs. To this type belongs *Stegobium paniceum* L. (Janisch, 1923).

Kleine (1918) is of the opinion that adults of *Stegobium* required food before laying, but this was contradicted by Janisch (1923). The author agrees with Janisch that the adults of this insect do not require food. The author has isolated hundreds of adults and never observed feeding. This was confirmed by the investigation of the gut. Adults of the flour-reared insects were kept in tubes containing flour, but it was impossible to overlook starch particles in the prepared gut in iodine in potassium iodide

solution. From the preliminary experiments and the dissections of the alimentary canals of the adults, the fore-, the middle-, and the hind-gut were almost always empty and often filled with air.

Further investigation was made to prove that the adults of the tobacco race do not take any food. This was confirmed by the following simple experiments. Ten pairs of newly emerged adults reared in tobacco, only virgin females were used, each pair was placed in a glass tube in ground tobacco. A similar experiment was set up in which the insects were kept in empty tubes. The females which were placed in ground tobacco lived as long as those which were kept without food, an average of 4 weeks. It is clear that if the adults of *Stegobium* require food, the adults which were supplied with ground tobacco on which they fed as larvae should have lived longer.

When it was confirmed that the adults of the two forms of *Stegobium* did not require food, the following experiment was performed to determine whether these beetles require an oviposition site.

Ten pairs of newly emerged adults of the flour-reared insects were used, each pair was placed in an empty glass tube whose mouth was covered with muslin held in position by rubber bands. The tubes were kept for 10 days at 25° C., and 75 % R.H., but no eggs were laid either in the tubes or on the muslin. The beetles were then removed to tubes of the same size with whole-meal flour on which the beetles fed as larvae and kept under the same conditions for two days, during which they produced a total of 281 eggs, all of which were laid on flour. They were again transferred to empty tubes in which they were left for the next two days, but they produced no eggs. On again being placed for two days in the flour they laid 99 eggs, but when placed again for two days in tubes this time with either black cotton wool or black scraps of paper, no eggs were laid. Lastly they were placed in flour for another two days after which the experiment was stopped and a total of 75 eggs were obtained. In all, a total of 455 eggs were laid in the flour.

A similar experiment was set up, in which the ten pairs of newly emerged adults were obtained from a tobacco culture, each pair was placed in an empty tube and kept for 10 days at a room temperature which fluctuated from 23 to 28° C., and with 75 % R.H., but no eggs were laid. The beetles were then removed to tubes containing ground tobacco and kept under the same conditions for two days, during which 179 eggs, all of which were laid on tobacco. They were again transferred to empty tubes and left for another two days, but no eggs were laid. On again being placed for two days in the ground tobacco, they laid 83 eggs, but when placed again for two days in tubes this time with either black cotton wool or black scraps of paper, no eggs were laid. Lastly they were placed in ground tobacco until they

died and a total of 45 eggs were obtained. In all, 307 eggs were laid in the ground tobacco.

Dick (1937) reported the same results for *Tribolium confusum, Tenebrio molitor* and *Dermestes vulpinus*. He found, that when these insects were placed in empty tubes they produced no eggs, and the eggs were only obtained when these insects were kept in flour.

The fact that adults of *Stegobium* reared in flour or in tobacco did not lay eggs in empty tubes suggested that the stimulus of an oviposition site was necessary. It seemed that the female adult of *Stegobium* was influenced in its choice of oviposition site by the smell of the host in which it was reared. This was confirmed by the following experiment.

A big piece of black cotton wool was contaminated with the smell of tobacco by keeping it in a glass tube containing ground tobacco and tightly covered with a cork lid for a period of one week. The colour of the cotton wool was chosen black so that when the eggs were laid on it, they could be easily seen. Ten pairs of newly emerged male and female adults of the tobacco race were used for the experimental work. Each pair was placed in an empty glass tube. The tubes were kept for 10 days under the same condition of temperature and humidity, but no eggs were laid either in the tubes or on the muslin. The beetles were then removed to tubes of the same size with odourless black cotton wool (i.e. without being in contact with tobacco) for two days but they produced no eggs. They were again transferred to tubes this time with black cotton wool contaminated with the smell of tobacco and kept under the same conditions for two days, during which they produced a total of 97 eggs, all of which were laid on the black cotton wool with the scent of tobacco. Again they were placed in new clean tubes containing odourless black cotton wool for another two days, but no eggs were laid. Lastly they were placed in tubes containing black cotton wool with the odour of tobacco for 5 days after which the experiment was stopped and a total of 77 eggs being obtained. Dissection were made of some dead females and in each case many developed eggs were found to be present in their ovarioles.

It is clear from the results obtained from the above experiment that the sense of smell was employed in the selection of oviposition site and in order to obtain oviposition, the adult female of *Stegobium* must receive an olfactory stimulation of the kind of food on which she fed as a larva.

These results obtained by the author were in agreement with the experiments conducted by Thorpe and Jones (1937) with the European race of *Nemeritis canescens* Grav. This ichneumonid parasite develops at the expense of the flour moths, *Ephestia kuehniella* (Zell.) and *Ephestia elutella* (Hb.), but although under normal conditions oviposition could only

very rarely be obtained upon the small wax moth *Meliphora grisella* (F.), a closely related insect to *Ephestia* and belonging to the same subfamily, yet it was found that by contaminating the larvae of *Meliphora* with the smell of the normal host (*Ephestia*) in various ways egg-laying could fairly be secured.

V. OVIPOSITION AND ITS RELATION TO HOST SELECTION

The « Host-selection principle » of Walsh and Hopkins, states that an adult female may be attracted for oviposition to the particular species on which she fed as a larva (see Craighead, 1921, and 1923).

In the preceding experiments which were designed for the choice of the oviposition site, the experimental insects were allowed to oviposit on food of the same kind as that they previously fed on during their larval stages.

In the following experiments the insects of the two strains of *Stegobium paniceum* L., oviposited on food different to that which they were originally bred from, or in other words, offered the choice of objects containing various kinds of food for laying eggs in order to find out, whether the type of oviposition site affects the rate of oviposition of *Stegobium* or, whether the females will be attracted to lay more eggs on their original host.

Larson (1927), Zacher (1929) and Herford (1935) have shown that various types of seeds stimulate to a different degree the oviposition rate of several species of *Bruchus*. Crombie (1941) has shown that the oviposition of *Rhizopertha dominica* Fab., is stimulated by the odour and the type of food used for oviposition.

The aim of the following experiments is not to give the exact number of eggs laid per adult female of either the flour race or the tobacco race under different conditions, but to find out : first, whether the adult female of each race will show marked preference for the egg laying in the host on which she fed as a larva, and ; second, to prove also that the sense of smell or the odour of the host in which the adult female had been reared, is the principle factor which plays an important part in the selection of oviposition site.

Accordingly eight series of experiments were carried out : in each series 10 pairs of *Stegobium* bred originally from whole-meal flour or ground tobacco were used.

The eight series were arranged as follows :

Series A : Control ; insects bred originally from whole-meal flour and ovipositing on the same kind of flour.

Series B : Insects bred originally from whole-meal flour and ovipositing on ground tobacco.

Series C : Control ; insects bred originally from ground tobacco and ovipositing on the same kind of tobacco.

Series D : Insects bred originally from tobacco and ovipositing on whole-meal flour.

Series E : As D, but the whole-meal flour is contaminated with the smell of tobacco. This was made by putting a thin layer of flour in between two leaves of tobacco and kept under this condition for 10 days.

Series F : As D, but the whole-meal flour is supplemented with 10 % ground tobacco.

Series G : As D, but the whole-meal flour is supplemented with 30 % ground tobacco.

Series H : As D, but the whole-meal flour is supplemented with 50 % ground tobacco.

The experiments of series A and B were conducted at 25° C., with 75 % R.H., while those of series C to H were conducted at a room temperature which fluctuated from 23 to 28°C., with 75 % R.H. Glass tubes 2×1 inch were used, each tube containing one male and one female *Stegobium*. The eggs laid in each tube were counted and removed daily for a period of 10 days only. A summary of data of oviposition rate of each series of experiments is given in Table II.

Results

It will be seen from Table II, that the females which had been bred on one particular food and put in the same food for oviposition (series A and C), produced more eggs than those which were reared and oviposited in different foods.

Table II

The stimuli inducing oviposition

SERIES	REARING FOOD	OVIPOSITION SITE	TOTAL EGGS PER FEMALE IN 10 DAYS		TOTAL EGGS OF 10 FEMALES
			RANGE	MEAN	
A	Whole-meal flour	Whole-meal flour	53 - 111	79.2	792
B	Whole-meal flour	Ground tobacco	16 - 25	23.3	233
C	Ground tobacco	Ground tobacco	35 - 93	56 5	565
D	Ground tobacco	Whole-meal flour	—	—	—
E	Ground tobacco	As D + smell of tobacco	2 - 15	5.7	57
F	Ground tobacco	As D + 10 % tobacco	9 - 22	13.5	135
G	Ground tobacco	As D + 30 % tobacco	14 - 31	19.7	197
H	Ground tobacco	As D + 50 % tobacco	27 - 45	32.9	329

The females of series A produced a total of 792 eggs, but there was a sharp drop in the rate of oviposition in series B in which the females were reared in whole-meal flour and oviposited in ground tobacco, a total of 233 eggs were obtained. On the other hand, the females of series C produced a

total of 565 eggs, whereas no eggs at all were laid in series D. It appears therefore, that in the absence of the odour of food (i.e. the odour of tobacco) the full oviposition response is not evoked and the insect may be said to exercise restraint. In series E there was no tobacco added at all, but the flour was only contaminated with the smell of tobacco. It seemed that the presence of the smell of tobacco in the flour induced the females to lay a few eggs (compare D and E) a total of 57 eggs were obtained.

It is to be noticed that the females of series E were stimulated by the smell of tobacco. In this behaviour *Stegobium* resembles *Rhizopertha dominica* (Crombie, 1941), and *Pimpla instigator* (Picard, 1922), which will not oviposit unless stimulated by the odour of its host's food.

When the females in series F, G, and H had combinations of flour and ground tobacco in the proportion of 10, 30, and 50 % tobacco, a great difference was made to their rate of oviposition. The presence of actual tobacco in the flour induced the females to lay eggs at a greater rate (compare series F, G, and H, with series D). The rate of oviposition was increased (compare E and F) by supplementing the flour with 10 % ground tobacco, a total of 135 eggs were obtained. By increasing the addition of ground tobacco to the flour by 30 and 50 %, there was a corresponding increase in the total number of eggs, a total being 197 and 329 eggs respectively.

VI. DEVELOPMENT AND ITS RELATION TO HOST SELECTION

In the course of the experimental work the author discovered that the larvae of the flour-reared insects could be reared without great difficulty upon various types of food (Azab, 1953). Among these types of food, whole-meal flour was evidently sufficient and satisfactory, as evidenced by (1) normal growth, (2) small mortality, and (3) ease in moulting.

On the other hand, oviposition of the tobacco-reared insects could not be obtained upon a new host such as whole-meal flour but when the latter was mixed with tobacco or contaminated with the smell of tobacco a few eggs could be secured.

Therefore, many experiments were performed, the aim of which was : first, to find out whether the eggs laid on tobacco leaves by the females of the flour race will hatch and whether the hatched larvae can be reared on tobacco and reach maturity ; second, to attempt to rear the tobacco race in whole-meal flour and to find out if the adults of this race will be able to adopt themselves to flour.

Results

A. *Stegobium* reared on whole-meal flour

The following experiments were carried out at 25° C., and 75 % relative humidity. All the experimental insects were reared in whole-meal flour.

In the first experiment ten glass tubes, each containing a small piece of tobacco leaf were used, in each tube a newly emerged male and female adult were introduced. The tubes were left untouched until the females laid all their eggs on the tobacco. The eggs were not removed but left on the tobacco leaves and incubated under the same condition of temperature and humidity. In no instance did a larva hatch and most of the eggs were collapsed and in a few cases the larvae were found dead inside the egg-shell with their heads protruding from the eggs, such eggs being dark brownish in colour.

In the next experiment, 100 eggs newly laid in flour by females of flour race were obtained. Fifty eggs were placed singly in glass tubes, each containing a piece of tobacco leaf. The other 50 eggs were placed in five empty glass tubes, 10 eggs in each. None of the eggs placed on tobacco leaves hatched while 45 out of the 50 eggs kept in empty glass tubes hatched.

A third experiment was performed in which the forty-five larvae hatched in the previous experiment were divided into three groups each containing 15 larvae. The larvae of each group were placed singly in a glass tube. One group was fed on tobacco leaves, the second on ground tobacco, and the third on cigarette tobacco. All the young larvae died within a few days from the commencement of the experiment. The larvae fed on the tobacco leaves died in between 4 and 9 days, those fed on ground tobacco died in between 2 and 4 days, while on the cigarette tobacco died in between 2 and 6 days.

Dissections were made to find out whether these larvae had fed on tobacco during the period of their survival, but their alimentary canals were always found empty. Janisch (1923) stated that the first instar larvae can live without food up to 10 days. Therefore, it was quite likely that these larvae did not feed on tobacco. This latter point was confirmed by the author, by examining the pits of tobacco leaves where no signs of eating were found or any trace of frass which proves that no food was eaten.

Another experiment was set up, this time when the author found that the first larval instars failed to develop on tobacco, attempts were made to breed the first instar larvae on their original host (the whole-meal flour) until they reached the second instar. Twenty larvae of that stage were transferred singly into glass tubes containing tobacco leaves and kept under the same condition of temperature and humidity. All the 20 larvae died in between 8 and 11 days from the start of the experiment. Not a single larva reached the third instar.

In a final experiment, using the same set up, the third and the fourth larval instars were used. After 6 days from the start of the experiment white patches started to appear on the skin of their bodies and the larvae shrank slightly and became greyish in colour and inactive. Later these white patches turned dirty brown after which the larvae dried up within 9 to 12 days. The

larvae of the third instar did not reach the fourth stage nor did those of the fourth instar became pupae. Some of these larvae were dissected but no trace of tobacco was found in the alimentary canals.

From the preceding experiments in which all the eggs failed to hatch and no larvae developed on tobacco, the following conclusion may be drawn.

(1) Tobacco cannot serve as food for the larvae of *Stegobium* reared from whole-meal flour.

(2) Tobacco inhibits the hatching of eggs and the development of the larvae of the flour race.

(3) The larvae of the flour-reared insects exhibit marked preference for their original host species in which their parents were reared as larvae. The larvae appear to be attracted to its original host by the sense of smell.

The fact that tobacco did not serve as food for the larvae of the flour race, was confirmed by the examination of the alimentary canals of the larvae which were found always to be empty or by examining the pits of tobacco which were found untouched.

Further investigation was made to find out whether the tobacco and its smell inhibit the hatching of eggs and the development of the larvae of the flour race. An experiment was performed in which 2 pairs of newly emerged male and female adults bred in flour were introduced into a glass tube covered with muslin and containing small pieces of tobacco leaves. The females were under continuous observation until they started to lay eggs on the pits of the tobacco leaves. Fifty eggs were immediately removed carefully and transferred into ten glass tubes, each containing whole-meal flour, their original host and five eggs. These tubes were kept under the same condition of temperature and humidity. After 8 days from the transference of the eggs, ninety-five per cent of the eggs hatched and eighty-six per cent of the hatched larvae reached pupation and all emerged as normal adults.

It will be gathered from the preceding experiments that it was impossible for the flour-reared *Stegobium* to become adopted to tobacco, although egg-laying by the female of the flour race was secured on tobacco. These results afforded strong support to Pictet's experiments (1911) working with the larvae of *Lasiocampa quercus*. The larvae feed upon deciduous trees and bushes, but when they placed upon *Pinus* many of them died.

Similar results were also obtained by Woods (1915) working on the Trypetid fly *Rhagoletis pomonella*. The larvae of this insect have long been known to live in the blueberry in North America and in apple in North-Eastern States. According to this author, this fly has developed into two distinct races distinguished by the small size of both larvae and adults derived from blueberry as compared with those from apple. Attempts to transfer the apple race to blueberry and vice versa were unsuccessful, the two forms being seemingly independent.

Lal (1934), in Edinburgh has discovred two biological races of the common hemipterous insect *Psylla mali*. One race is attached to hawthorn and the other race to apple. Lal has shown that the imagines of both forms are identical and the only differences are those shown by the nymphs. The two forms are closely confined to their individual food-plants and they do not inter-breed and the nymph of either, when transferred to the food-plants of the other, does not survive long.

B. *Stegobium* reared on tobacco

This race of *Stegobium* is very easily reared in the laboratory upon cured and uncured tobacco and completes its life-history in the relatively short period 6-8 weeks at optimum temperature. Many cultures of this race have been reared in this Department continuously during the last 2 years. It was proved experimentally that when the eggs laid on tobacco by the females of the tobacco race were transferred into tubes containing whole-meal flour, the eggs hatched, but the hatched larvae did not survive long and all died within a few days from hunger because they did not feed on flour at all.

To obtain further informations, experiments were carried out to raise the tobacco race from the first larval instar to the adult stage on whole-meal flour. Since the females of the tobacco race failed to lay their eggs in flour, newly hatched larvae of not more than 6 hours old were obtained from ground tobacco cultures and were used for the experimental study.

Three series of experiments were carried out : in each series five glass tubes were used, each tube containing 10 newly hatched larvae ; thus 150 larvae were used in all. In series A the control, ground tobacco was placed in each tube. In series B, whole-meal flour alone was used as food for the larvae. In series C, a culture was made by mixing whole-meal flour with ground tobacco in the proportion of 1 : 1. The experiments were conducted at room temperature which fluctuated from 23 to 28° C., and 75 % relative humidity.

In series A the control, the larvae grew quite normal and the larval life being significantly shorter than on the diet used in series C. Ninety-two per cent of the larvae of series A reached pupation and all emerged as normal adults. In series B, where whole-meal flour was placed in the tubes, all the larvae died in between 5-9 days from the commencement of the experiment. It is interesting to know that the larvae placed in flour were not attracted to that new host and tended to climb up to the top of the tubes and remained attached to the muslin covering each tube for a long time or sometimes they began to wander and climb over the wall of the tube and in the latter case, when the larvae were removed by a fine brush and placed on the flour, they started to wander again and never settled down on the flour. Dissections

were made of the dead larvae and in each case the alimentary canal was always found to be empty and also no trace of frass was found which proves that no food was eaten. In series C, where the food was a mixture of equal portions of whole-meal flour and ground tobacco, the larvae suffered high mortality ; fifteen died, nine in the first instar, four in the second instar and two in the third instar. Thirty-five larvae reached pupation and all emerged as normal adults representing 70 % of the total. The high mortality on this mixture diet was not due to insufficient ground tobacco as, there was still plenty of it not consumed. The tobacco proved to be the only source of food for the larvae which survived and reached adult stage.

Dissections were made of the dead larvae of the different instars, but the alimentary canals were found to be contained food which in such condition was difficult to judge whether it was the remaining of tobacco food or flour food or a mixture of both. In order to confirm and to prove that the larvae of series C, had never touched flour but survived on tobacco alone until they reached pupation, the following experiment was set up :

Fifteen newly emerged larvae of the same age and of the same imbred stock as those which were used in series C were obtained. These larvae were all placed in a glass tube containing the same mixture diet as in C, but the flour this time was slightly stained with methylane blue. Dissections were made of the larvae of the second, the third, and the fourth instars respectively. In each case the alimentary canal of each larva was found to be contained food which was absolutely colourless. From this, it was inferred that the larvae had fed solely on tobacco as there was no trace of stained flour in their alimentary canals.

VII. OLFACTOMETER EXPERIMENTS

Olfaction is important in the lives of insects because it enables many kinds to find their food, besides enabling the female to discover a suitable medium for oviposition.

Preliminary experiments carried out by the author on *Stegobium paniceum* L., had clearly shown odour to be the dominant factor in host-selection. This was proved by the following experiments.

In the first experiment, pits of tobacco leaves were laid on a piece of white paper about 2-3 cms. from ten freshly hatched larvae of the tobacco-reared insects. On the opposite side of the larvae at the same distance a small portion of flour was placed and the larvae were left to make a choice. They hesitated for a while, then started to crawl towards the direction of the tobacco leaves.

In another experiment, the pieces of tobacco leaves were placed behind the larvae at a distant of 2 cms. They hesitated, turned round and then

proceeded towards the tobacco. To decide the question as to whether the sense of smell of tobacco is the guiding factor in the change of direction of the larvae in the previous experiments, a similar experiment using the same set up was performed, but this time pieces of coal were substituted for the tobacco, the results were completely negative and the larvae were not in the least influenced.

Further observation was made, this time the adults of *Stegobium* reared from tobacco were used. Two portions, one of ground tobacco and the other of flour were placed in a small card-board box at a distance of about 6 inches apart from each other. Half way between the two portions of tobacco and the flour, ten all newly emerged female adults were released in the centre of the box. The beetles started to run here and there in different directions and in the end all the females except two started to progress towards the tobacco and finally gathered arround it. This experiment was repeated three times and in each time the places of the two portions of tobacco and flour were changed, but the same results were obtained and the beetles showed strong attraction to their normal host, the tobacco. From the preceding experiments the following may be concluded : The wandering of the adults *Stegobium* and its larva is at first a simple searching movement which is

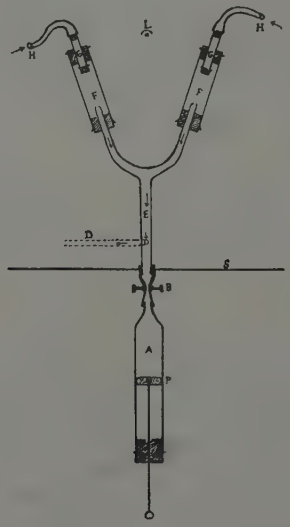

Fig. 2: Diagram of olfactometer (Arrows indicate direction of air flow) [after Thorpe].

strongly positively influenced by olfactory stimulus. If the insect turns away from the direction of the food, the sense of smell corrects this error.

The author also, showed by means of olfactometer experiments, that the egg-laying female of *Stegobium* reared from tobacco was first attracted to the odour of its host's food on which she fed as a larva.

The olfactometer used (Fig. 2) was of the type described by Thorpe (1937, 1938) which is essentially a Y-shaped tube. The insects to be investigated were placed in the tube A and were allowed to settle down, the clip B being closed. The odoriferous substance to be tested was put in one or other of the tubes GG, each tube was closed by a plug of cotton wool at one end and by a cap of bolting silk at the other. Air was then drawn through the tube D by means of a suction pump and the strengths of the currents in each arm being made equal by flowmeters. When a steady flow had been established the clip B was opened so that the insects in A could make their way towards the light L, from which they had been protected by the screen S. If any insects found difficulty in leaving A, the space in which they were enclosed was gradually reduced by the plunger P until all had passed through. For these experiments the apparatus was used horizontally and the glass ground inside on the bottom half of the tube. This enable the insects to walk. On reaching the fork of the glass tube E they were forced to make a choice. Those going each way were caught in the tubes FF, counted and the results recorded. The apparatus was washed at intervals with running water and alcohol, and the « bait » changed from arm to arm to eliminate errors due to accumulation of dust from the host food, or to the traces left by the *Stegobium* themselves.

The experiments were carried out in a room temperature at 27-28° C. (no relative humidity was recorded). Only the newly emerged female adults of *Stegobium* reared from tobacco were used for the olfactometer experiments. These females had not had any previous opportunity for oviposition.

Results

As a first experiment it was desirable to determine whether the whole-meal flour without any traces of tobacco itself exercised any attraction for *Stegobium* reared on tobacco. Accordingly a group of 25 female *Stegobium* were put through the olfactometer, one arm of which contained whole-meal flour, the other arm being empty.

The results of these experiments are shown in Table III. It will be seen that out of a total of 52 choices the arm containing the whole-meal flour was favoured 7 times or 13.4 % and the empty arm 45 times. From the series we can therefore conclude that the smell of whole-meal flour has no attraction for *Stegobium* reared from tobacco.

The next point was to determine the intensity of attraction exerted by the scent of tobacco on *Stegobium* reared upon this, their normal host. For

this purpose some ground tobacco was placed in one arm of the olfactometer, the other being left blank. The results of this set of experiments in which 35 individuals of *Stegobium* were employed are given in Table IV. It will be seen that there is a very strong preference for the arm containing the

TABLE III

Responses of twenty-five individuals of Stegobium paniceum *L., (reared from tobacco) to whole-meal flour in olfactometer*

EXPERIMENTS	NUMBER OF INSECTS		TOTAL NUMBER OF INSECTS IN THE TWO ARMS
	ARM WITH WHOLE-MEAL FLOUR	ARM BLANK	
1	2	5	7
2	1	6	7
3	—	4	4
4	2	8	10
5	1	6	7
6	1	5	6
7	—	7	7
8	—	4	4
Total of choics	7	45	52

= Whole-meal flour 13.4%; = Blank 86.6%.

tobacco, out of a total of 126 choices the arm containing tobacco was favoured 114 times or 90.4 % and the empty arm 12 times.

Following this result the reaction of tobacco-reared *Stegobium* to a choice of the two hosts was investigated ; a portion of whole-meal flour being placed in one arm of the apparatus and a portion of the same weight

TABLE IV

Responses of thirty-five individuals of Stegobium paniceum L., *(reared from tobacco) to ground tobacco in olfactometer*

EXPERIMENTS	NUMBER OF INSECTS		TOTAL NUMBER OF INSECTS IN THE TWO ARMS
	ARM WITH TOBACCO	ARM BLANK	
1	23	2	25
2	18	4	22
3	25	1	26
4	28	—	28
5	20	5	25
Total ofchoices	114	12	126

= Tobacco 90.4%; = Blank 9.6%

of ground tobacco in the other. Careful precautions were taken to prevent the contamination of one of the hosts by the smell of the other.

The results of a series of experiments using thirty-five individuals are given in Table V. It will be seen that there is no evidence that the odour of whole-meal flour exerts any attraction for *Stegobium*.

TABLE V

Responses of thirty-five individuals of Stegobium paniceum L. *(reared from tobacco) to tobacco and whole-meal flour in olfactometer*

EXPERIMENTS	NUMBER OF INSECTS		TOTAL NUMBER OF INSECTS IN THE TWO ARMS
	ARM WITH TOBACCO	ARM WITH WHOLE-MEAL FLOUR	
1	20	2	22
2	27	0	27
3	15	1	16
4	28	1	29
5	24	0	24
6	18	2	20
7	29	1	30
8	20	0	20
Total of choices	181	7	188
	= Tobacco 96.7%;	= Whole-meal flour 3.3%	

From these results therefore we may conclude that *Stegobium* reared on its normal host tobacco, while responding very strongly to the smell of tobacco, is not at all attracted by the odour of whole-meal flour. Similar results were obtained by Thorpe and Jones (1937). These authors used the same olfactometer to investigate the olfactory conditioning in the endoparasitic Ichneumonid (Hymenoptera) *Nemeritis canescens* Grav. After several experiments they concluded that there is a strong germinally fixed tendency in *Nemeritis canescens* to follow up the odour of its primary host the Pyralid moth *Ephestia kuehniella* Zell., and can find this host almost entirely by the sense of smell which resides in the antennae. Crombie (1941), has found the same results with *Rhizopertha dominica*. He reports that *Rhizopertha* appears to be first attracted to its food, in which it also oviposits, by the sense of smell.

VIII. SUMMARY

(1) The curious habit of *Stegobium paniceum* L., of attacking a great variety of stored-food and other material was associated with the development of two briological strains or races with marked different rates of development.

There might be possibly more than two biological races of this insect. This suggestion of biological races clearly needs further study.

(2) One race of *Stegobium* is attached to grain and its products in Europe and the other race develops on tobacco in America.

(3) The imagines of the two races are structurally identical, but exhibit differences in size, in colour, in cocoon texture and in method of oviposition.

(4) It has been proved experimentally that the adults of the two races of *Stegobium* do not require food and are able to complete their adult life and lay their normal number of eggs owing to the reserves of fat which they have in their bodies when they are newly emerged.

(5) A stimulus for oviposition of the two races was necessary, *Stegobium*, however, though short-lived, requires an oviposition site.

(6) *Stegobium* shows a marked preference for the host in which it has been originally bred, since the beetles reared on either whole-meal flour or tobacco produced more eggs on their original hosts than on other hosts offered as oviposition site.

(7) All attempts to transfer the flour race to tobacco and vice-versa have resulted in failure.

(8) Evidence is presented to show that the sense of smell is a dominant factor in host-selection as the ovipositing females of *Stegobium* of both races are guided by smell in selecting their oviposition site.

(9) The females when offered the choice of objects containing various kinds of food to oviposit on, they laid all their eggs on the kind of food in which they had been reared as larvae.

(10) The attraction to the host species has been demonstrated experimentally in an olfactometer of the type described by Thorpe (1937). In this apparatus the insects reared from tobacco show strong attraction to the tobacco their normal host.

(11) The importance of the subject lies in its relation to the so-called « Hopkins host-selection principle » and its bearing on the problem of the origin of biological races in insects.

IX. ACKNOWLEDGMENTS

The experimental work dealing with the new biological race of *Stegobium paniceum* L. (the tobacco race) which was discovered by the author in 1950 was carried at the Entomology Department, Faculty of Agriculture, Fouad I University, Giza.

The author gratefully acknowledges his indebtedness to Dr. W. H. Thorpe, of Cambridge University, for recommending the type of the olfactometer used by him during my study in England, this olfactometer was of great help to me in this present study.

The results recorded here (for comparison) for *Stegobium paniceum* L., of the flour race, were obtained during my work on this insect at the Biological Field Station, Slough (England). The author is greatly indebted to Prof J.W. Munro and to Dr. O.W. Richards for their many helpful suggestions and criticism.

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Contribution to the knowledge of the Agrotidæ-Trifinæ of Kashmir LXIV (1)

[Lepidoptera]

(with 4 Plates)

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The « Trifinae » collected in 1942 by Mr. E.P. Wiltshire in Kashmir which he has kindly submitted to me for examination comprise 19 species in about 50 specimens, of which 4 are new. They come from the following localities :

1. Tragbal (9000 ft. = 2743 m.), north of Bandipura (Wular Lake), south of Koragbal.

2. Koragbal (8750 ft. = 2667 m.), north of Tragbal.

3. Kanzalwan (8000 ft. = 2438 m.), north of Koragbal.

4. Badwan Gurais (7900 ft. = 2407 m.), Gurais Valley, upper valley of Kishenganga River, north of Kanzalwan.

5. Taobat (7400 ft. = 2255 m.), Kishenganga valley, west of Kanzalwan, on Kishenganga River, lower than preceding locality.

6. Gulmarg (8800 ft. = 2682 m.) (Baramullah), west of Srinagar, SSW. of Wular Lake, in the Pir Panjal Range.

7. Pachatar Bridge (7400 ft. = 2255 m.), near Yus Maidan, frontier district, south of Srinagar in the Pir Panjal Range.

8. Pir Panjal Range, an independent Range south of the Kashmir plain. The peaks reach 4000 m., but Mr. E.P. Wiltshire did not collect above 3000 m.

These last three localities are south of the Kashmir plain, the others to the north.

According to the information kindly given to me by Mr. E.P. Wiltshire, all these localities have the same biotype with roughly the same vegetation and the same rainfall.

This biotype consists of pine-forest mingled with large deciduous trees, especially at the lower altitudes ; these trees occur especially below 8000 ft.

(1) See : LXIII, in *Zeitschrift der Wiener entomologischen Gesellschaft*, 1953, p. 239.

(2438 m.) but *Betula* is an exception as it is found even higher than the pines. The trees do not go beyond 3000 m. (about 10.000 ft.). Mr. E.P. Wiltshire did not collect below 5000 ft., and for this reason almost all his captures belong to the palaearctic Fauna.

Works concerning Heterocera in general and more particularly *Trifinae,* published up to the present day on Kashmir are limited both in number and importance. This country has hardly been explored and naturalists seem to have favoured Rhopalocera to the detriment of others.

We can quote :

Kollar and Redtenbacher, Lepidoptera, in Carl Freih. v. Hügel's Kaschmir, IV, 1948 ;

Moore, Description of new species of Lepidoptera collected by Dr. Stoliczka during the Indian Government Mission to Yarkand 1873 (*Ann. Mag. Nat. Hist,* (4), I, p. 327 and following.

Moore, Lepidoptera in « Scientific Results of the second Yarkand Mission » (Calcutta, 1879). These studies however do not give much useful information on Lepidoptera, species from Kashmir having mostly been described in separate works by Hampson (Moths of British India, Cat. Lep. Phal., Vol. IV to IX), Moore in *Proc. Zool. Soc.* (London), Swinhoe, etc.

From what is actually known of the fauna of Kashmir and confirmed by E.P. Wiltshire's recent captures, it is possible to estimate that this may be separated into four essential geographical categories, though further exploration of this barely known region may modify this point of view. These categories are :

(1) A West-Chinese-Himalayan category containing bush and woodland species which spread all along the mountain ranges and stretch out far up into the northern parts of Western China (reaching Mien-Shan). This category appears to be the most important and Kashmir could be regarded as the extreme western limit of extension for a certain number of these species (*Diarsia stictica* Pouj.) ; others most certainly spread up to Pamir and even into the Hindu-Kusch (2) (several large *Cryphia* (*Bryophila* sensu lato) and peculiar to the Himalayan Chain).

(2) A category composed by some euryoecous species of rather eremic character and of euro-siberian origin, which occurs also up to Europe (*Euxoa conspicua* Hb., *Rhyacia simulans* Hfn.).

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(2) See « Bericht ueber die entomologischen Sammelergebnisse der Deutschen Hindukusch-Expedition 1935 » by Dr. Hans Sachtleben in « Deutsche im Hindukusch », Berlin, 1937, pp. 291-294, and « Entomologische Sammelergebnisse der Deutschen Hindukusch-Expedition 1935 der Deutschen Forschungsgemeinschaft » in *Arbeiten ueber morphologische und taxonomische Entomologie aus Berlin-Dahlem,* 3, pp. 173-213, 12 Text-fig., Berlin-Dahlem, 1936.

(3) A category which pending more complete information may be considered as endemic, containing a whole series belonging to all Subfamilies and different biotopes (such as *Ochropleura herculea* Cti.-Drdt., *Mamestra tenebra* Hps., *Bryopolia virescens* Hps., *Apatele gastridia* Swinh., etc.). However it is possible and even probable, that these supposed endemics belong to the Himalayan Chain, of which the fauna is barely known. They will very probably be found also in Ladak, Sikkim, and Bhutan and even much further East (such in the case of many *Trachea* O. and *Euplexia* Steph.), or further West, in Pamir and Hindu-Kusch.

If however this endemic character proved later to be beyond doubt, it would be of considerable zoogeographical interest. One would then be inclined to suggest that these endemics are the remains of the very rich populations that previously inhabited all Pamir and which survived practically in the whole of Kashmir, having escaped the considerable modifications which so profoundly affected these mountain ranges throughout the ages.

Nevertheless, it is essential to bear in mind that only very careful use should be made of the term « endemic », more particularly so when practically unexplored regions are concerned. The endemic character imputed to a species is often due to the lack of knowledge of its real geographical expansion. Surprises were caused when certain so-called insular endemics of the Mediterranean (Corsica, Crete, Cyprus) and Canary Islands, were later found on the European Continent (*Euxoa haverkampfi* Stndf., *Mamestra corsica* Rbr., *Caradrina fuscicornis* Rbr., *Amathes cohaesa* H.-S. (*pulverea* Hps), in Africa (*Euxoa canariensis* Rbl., *Evisa schawerdae* Reisser), in Asia (*Euxoa canariensis* Rbl. too, which reach Beluchistan !, *Evisa schawerdae* Rssr., which were found in Syria and in Iraq by Mr. E.P. Wiltshire, etc.). It is obvious that these species have no endemic character.

(4) This last category of the fauna of Kashmir is made up of species of subtropical origin or even tropical (oriental) which have moved up from the Indian plains, many are of Gondwanic origin (African).

To sum up this short study of the fauna of Kashmir, it may be said that this region has a very marked West-Chinese-Himalayan character, with a certain percentage of central-asian eremic elements and of tropical (oriental) species. Attention should be drawn to the complete absence, as far as is known at present, of elements from the Armeno-Causasian-Iranian centre of dispersion (vorderasiatisch-mediterran of the Germans), which are still numerous in Persia and Western Afghanistan. Apparently the Pamir massif and the Tiritch-mir massif have been a barrier in the eastward spread of these species, the species of Eremic character in Kashmir originating doubtless in Turkistan and Central-Asia.

AGROTINAE

Euxoa conspicua Hb.

(Europ. Schmett., Noct., ff. 718-719)

Kanzalwan, 1 ♀, 19.VI. 1942, similar to the specimens of Central Asia. One of the most widely spread species of *Euxoa* Hb. of the desert regions of palaearctic Asia Already notified from Kashmir and Punjab. Reach Pyrenees and Spain towards the West. Does not appear to extend to the East beyond north Mongolia. The records from Amur are very probably referable to *Euxoa intracta* Wlk. Euro-siberian.

Agrotis segetum Schiff.

(Wien. Verz., pp. 81, 252, ff. 3, a, b, 1775)

Kanzalwan, 18.vi.1942, 1 specimen ; Badwan Gurais, 20.vi. 1942, 1 specimen ; Koragbal, 22.vi. 1942, 1 specimen ; below Taobat (7000 ft.), 25.vi.1942, 1 specimen.

Euro-siberian.

Agrotis duosigna Hps. (Pl. I, fig. 12)

(Cat. Lep. Phal., IV, p. 350, 1903)

Kanzalwan, 19.vi.1942, 6 specimens ; Koragbal, 22.vi.1942, 2 specimens ; Badwan Gurais, 20.vi.1942, 1 specimen.

Species closely related to *Agr. exclamationis* L. but distinct. At present only known from Kashmir.

Kashmir endemic ?

Agrotis ipsilon Hfn.

(*Berl. Mag.*, III, p. 416, 1766)

Taobat, 17.vi.1942, 1 specimen ; Badwan Gurais, 20.vi.1942, 1 specimen.

Cosmopolitan.

Ochropleura herculea Cti.-Drdt. (Pl. I, fig. 1)

(Seitz, Suppl., Bd. III, p. 64, pl. 8 e, 1933)

Kanzalwan, 19.vi.1942, 1 ♀.

This species (described as ssp. of *flammatra* Schiff.) resembles a large *flammatra* Schiff. but is definitely distinct as appears from its genitalia (shown on Pl. I, fig. 11) by comparison with those of *flammatra* Schiff. (Pl. I, fig. 13). I know it at present only from Kashmir and Spiti. It is probable that the notifications of *flammatra* Schiff. from this region and from Punjab are referable to *herculea* Cti.-Drdt.

Externally *herculea* differs from *flammatra* by its very large size, its forewings more strongly marked and above all by its reddish-brown groundcolour which does not exist in *flammatra*, especially in those from Central Asia which are very light in colour and weakly marked (*deleta* Kollar, *centra-*

lasiae Wgnr., *obsoleta* Cti.). A very interesting species from a zoogeographical point of view.

Kashmir endemic ?

Rhyacia simulans arenacea Hps.

(Novitates Zoologicae, 1907, p. 245 [*pseudosimulans* Kozh.])

Gulmarg, 24.v.1942, 1 ♂.

Euro-Siberian.

Diarsia stictica Pouj. (Pl. I, figs. 2 and 3)

(*Bull. Soc. ent. Fr.*, VII, p. lxviii, 1887 ; ssp. *viaria* Swinhoe, *P.Z.S.*, 1889, p. 412)

Kanzalwan, 19.vii.1942, 1 ♂ very worn and 1 ♀ of the form *semipleta* Warr ; Pir Panjal Range, 1 ♂ ♀ very worn and 1 ♀ of the form *semipleta* Warr. ; Pachatar Bridge, 3.vi.1942 ; Tragbal, 1 ♀, 24.vi.1942 ; Badwan Gurais, 1 ♀ of the form *semipleta* Warr., 20.vi.1942 ; Taobat (Kishenganga Valley), 1 ♀, 16.vi.1942.

This species, described by Poujade in 1887 from Mou-pin (Sze-Tschwan (China) is a species very distinct from all other *Diarsia* Hb. It is with *D. deparca* Butl. bona sp., the only palaearctic species of the genus which has the antennae strongly bipectinated (3). I have figured the Type in « Lepidoptera », T. III, 1928, pl. V, fig. 8 and the ♂ genitalia in *Zeitsch. d. Wien. ent. Ges.*, XXXIII, 1948, pl. 7, fig. 24, and here (Pl. I, fig. 14). It appears to be very extensively spread over the whole Himalayan Range as far as Kashmir in West and also goes a considerable way Eastwards in the Mountain ranges of Western China. I have kept the name of *viaria* Swinhoe to distinguish the Kashmir form, described from Umballa, but it scarcely differs from the typical form from Western China. The form *semipleta* Warr., characterised by black spots in the cell on each side of the orbicular, is a character of polyphyletic design among the *Agrotinae* and may appear in any genus. It may especially be observed in species belonging to wholly different genera, such as *Eugnorisma* Brsn., *Eugraphe* Hb., *Ochropleura* Hb., *Amathes* Hb., *Cerastis* O., etc. This form may also appear in all the localities where the species occurs, but generally speaking only in a very small proportion of specimens. It is found also in *Diarsia fannyi* Cti.-Drdt.

West-Chinese-Himalayan.

HADENINAE

Mythimna mesotrosta Pglr. kashmirensis n. ssp. or n. sp. ? (Pl. I, fig. 8)

(Iris, XII, p. 295, pl. 9, fig. 9, 1899)

Mr. E.P. Wiltshire has taken on the Pir Panjal one ♀ example, which I have compared with the Type of *M. mesotrosta* Pglr. kindly sent

(3) Cf. Boursin « Eine neue *Diarsia* aus dem pazifisch-paläarktischen Faunenkreis », in *Zeitschr. d. Wien. ent. Ges.*, XXVIII, 1943, p. 343.

to me for comparison by Prof. M. Hering, of the Berlin Museum. I attribute it to this species under reserves and with hesitation. It is closely related to it by its general ground-colour and by its markings, but differs by its smaller expanse (expanse of forewing 14 mm., *mesotrosta* 15 mm.), by its slightly darker colour, by a dark fascia on the place of the claviform, which is lacking in *mesotrosta,* and by the underside of both wings : in *kashmirensis* the hindwing is definitely lighter, though the example is a ♀, and on the forewing the costa and the postmedian space, up to the terminal border, are even light, while the underside of *mesotrosta* is uniformly dirty brown. Moreover the form of the forewing in *kashmirensis* is more square and the apex is not so produced as in *mesotrosta* Pglr. I distinguish provisionally this example as ssp. but it is very possible, that it constitutes a good species. I add here that the species described by Prof. M. Draudt in his work « Beiträge zur Kenntnis der Agrotiden-Fauna Chinas » in *Mitt. Münchn. ent. Ges.,* XL, 1950, p. 52, pl. IV, fig. 3, under the name *Cirphis mesotrostella* n. sp. is not a good species, but only a form of *mesotrosta* Pglr., which differs from the Type (from Kuku-nor) only by its reddish tinge. It is plainly a race from SW. China. This form is consequently very distinct from *kashmirensis.*

Holotype : 1 ♀, Pir Panjal Range, Pachatar Bridge, 3.vi.1942.

West-Chinese-Himalayan.

Mythimna unipuncta Haw.

(Lep. Brit., p. 174, 1809)

Srinagar, 18.v.1942, 2 specimens ; Nilnag, 5.vi.1942, 3 specimens ; Badwan Gurais, 25.vi.1942, 1 specimen.

Cosmopolitan.

CUCULLIINAE

Bryopolia n. gen. (Pl. II. figs. 15 and 16)

Proboscis, well developed. Palpi, porrect, rising very distinctly above the level of the frons, covered by long hairs at the base. Frons smooth. Eyes normal, large and well developed. ♂ antennae slightly serrate and ciliated or bipectinated with fairly long branches. Thorax, clothed chiefly with long, shaggy hair-like scales. Pro- and metathorax, without very characterised crests. Abdomen, with a heavy covering of hairs at the base and on the first segments, also a few slightly accentuated crests. Neuration of the forewing : 3, 4 and 5 from the lower angle of cell, 6 from upper angle, 9 from 10, anastomosing with 8 to form the areole : 11 from cell. Neuration of the hind-wing : 3 and 4 from the lower angle of cell ; 6 and 7 from upper angle or slightly stalked ; 8 anastomosing with the cell near base only.

Genitalia of the male : Uncus relatively short and very stout, broad and spatulate, or very short, little developed and terminating in a point

(*bacheri* Pglr.). Valvae large, broad and well developed, with borders nearly parallel, the external border oblique ; complete absence of Cucullus and Corona, and only a few fine hairs on the apex. The structure of the valves is composed solely of 2 or 3 finger-shaped appendices, well developed and placed towards the extremity in fan-shape, terminating in a more or less rounded point, the two first (one only in *bacheri* Pglr.) representing the harp and ampulla (sensu Pierce) and the third, the extension of the sacculus (extension of the sacculus of Pierce). Juxta in the form of a plate, very large and broad. Saccus normal. Aedoeagus, large and well developed, with external sclerotised distal bands ; the vesica armed with a central cluster of stout and fairly numerous cornuti.

Generotype : « *Bryomima* » *virescens* Hps. (Pl. II, fig. 15).

The genus includes also the following species : *Br. chrysospora* Brsn. n. sp., described hereafter ; *Br. chamaeleon* Alph., *Br. centralasiae* Stgr., *Br. extrita* Stgr., *tenuicornis* Alph., and *Br. bacheri* Pglr. This genus should find place in the classification between the genera *Eumichtis* Hb. and *Dasythorax* Stgr. (Typus : *poliana* Stgr.) (Pl. III, fig. 19) (4).

Affinities : The species mentioned above have been erroneously placed in the genus *Bryomima* Stgr. (typus : *carducha* Stgr.) with which they have nothing in common. This genus created to include *carducha* Stgr. contains in reality only small species measuring about 30 mm. and resembling *Cryphia* Hb. (*Bryophila*) species. In fact, it comprises only the following species : *carducha* Stgr., *codeti* Ob., *luteosordida* Osth. and *sinaïca* Wiltsh.; it is very close to *Lithophasia* Stgr. (typus : *venosula* Stgr.) if indeed not identical.

The differences between *Bryopolia* and *Bryomima* Stgr reside essentially in the characteristics of the Genitalia, as may be seen by the examination of figures 15, 16 and 17 of Plate II. The genitalia of *Bryomima* Stgr. (Pl. II, fig. 17) are of a very different type, the valves being relatively short and broad, without any appendix, and always terminating in one or two pointed ends, slightly curved downwards. Moreover the *Bryomima* appear to be mediterraneo-asiatic species of low and mean altitude and of desert regions, whilst the *Bryopolia,* with the exception of *bacheri* Pglr. of Palestine and North Africa, belong to the fauna of the mountainous regions of Turkestan and the western part of the Himalayan range.

The genus *Bryopolia* Brsn., by its general constitution and the external aspect of the species of which it is composed, is very much nearer to the genera *Antitype* Hb. and *Eumichtis* Hb. There is however a marked distinction in the characteristics of the genitalia, in the first, chiefly by the regular

(4) This genus contains only two species : *poliana* Stgr. and *anartina* Alph. the others, which were erroneously placed there, belong in fact to the genus *Autophila* Hb. (cf. Boursin in *Mitt. Münchn. ent. Ges.*, 1940, pp. 514-515 et seq.)

absence of the cucullus and the corona and the general form and structure of the valvas, and in the second, likewise by the absence of the cucullus and the corona, but mainly by the constitution of the aedoeagus, which is very special and very homogeneous in the case of *Eumichtis* Hb. I have figured (Pl. II, fig. 18) the ♂-genitalia of *Eumichtis variabile* Stertz. *Eumichtis* Hb. (5) is an atlanto-mediterranean genus, which comprises only the following species : *lichenea* Hb., *variabile* Stertz, *aurora* Trti., *rupicola* Trti. (described as *Agrotis*), *fiorii* Brsn., *lea* Stgr., *susica* Rgs. and another new species from Morocco which will be described shortly. These are exclusively north-african species, with the exception of *lichenea* Hb., which extends right up to England and *lea* Stgr. which occurs in Palestine. The other species of the *adusta-satura*-group, erroneously placed in the genus *Eumichtis* Hb. and for which the genus *Mniotype* Franel. has been recently created, belongs in fact to the genus *Blepharita* Hps. (typus : *amica* Tr.) (6) which seems very closely related to the North-American genera *Anytus* Grote and *Fishia* Grote, if with those not identical.

The genus *Bryopolia* forms a perfect transition between *Eumichtis* Hb. and *Dasythorax* Stgr. of which I have figured the type genitalia, *poliana* Stgr. (Pl. III, fig. 19), the genus *Dasythorax* Stgr. being itself a transition towards *Dasypolia* Gn.

I take the opportunity of the publication of this new genus to describe briefly here a new species from Zarafshan, which belongs to it, and which will be figured and described in greater detail later on.

Bryopolia chrysospora n. sp (7)

(preliminary description ; genitalia figured (Pl. II, fig. 16)

Closely related to *B. virescens* Hps. The differences reside essentially in the uncus, which is very much longer and less spatulate, the appendixes of the valves which are stouter and thicker, and of equal length, their base being definitely more sclerotized, the sacculus shorter and broader, the fultura inf. narrower and contracting towards the summit and forming a swelling in the middle. The aedoeagus definitely longer and narrower, the distal sclerotisation less marked and of a different form.

Holotype : 1 ♂, Zarafshan (Russian Turkestan) (Coll. Boursin).

Systematic position : This species should be placed next to *Br. virescens* Hps.

Bryopolia virescens Hps. (Pl. II, fig. 15)

(Moths India, II, p. 234, 1894)

Badwan Gurais, 21.vi.1942, 1 ♂.

Species known to date only from Kashmir (Dugi Pass (12.500 ft.),

(5) Cf. Boursin in *Mitt. Münch. ent. Ges.*, loc. cit., 1940, pp. 512-514.
(6) Cf. Boursin in *Zeitschr. f. Lepidopterologie*, Bd. 2, 1, 1952, pp. 59-60.
(7) From the Persian : « Zarafshan », « which spreads gold ».

Thompson). Endemic to Kashmir or rather confined to the Himalayan Chain.

APATELINAE (ACRONYCTINAE)

Apatele gastridia Swinhoe (Pl. IV, fig. 27)

(*Ann. Mag. Nat. Hist.*, (6), XV, p. 5, 1895)
(*Acronycta aceris* Hps., Moths Ind. II, p. 241, nec. L.)

Koragbal, 23.vi.42, 1 ♂.

A species known only from Kashmir.

? Kashmir endemic.

Cryphia ravuloides n. sp. (Pl. I, figs. 5 and 6)

(*Cr. ravula* Hps. p.p. nec Hübner, from Kashmir, in Cat. Lep. Phal., VII, p. 640, 1908)

♂ : Antennae finely ciliated, the length of the cilia slightly exceeding the diameter of the shaft.

This new species cannot be better characterised than by saying that it resembles superficially *Cr. ravula* Hb. almost exactly. The type of pattern is absolutely the same, which explains the confusion of Hampson, particularly the presence of pale patches at the base of the following, at the apex, and in the postmedian area at the base of the postmedian line on the inner margin. The only differences reside in the general colouration, which is greyer, less brown, the disc lacking the coppery brown tint nearly always present in *ravula*, and in the wing-shape, the wings being distinctly longer and narrower. On the hindwing underside, the discal spot and the postmedian and terminal lines are most distinctly marked. These characters however are less pronounced in the ♀. Moreover the ciliation of the ♂ antennae is longer in the new species than in *ravula*, in which the cilia are not longer than the diameter of the antenna-shaft.

But the principal characters of the new species lie in the ♂-genitalia (Pl. III, fig. 23). These are of the same type as those of the *ravula* Hb.-group, and come closest to those of *Cr. ereptricula* Tr. b. sp. (8) (Pl. III, fig. 22), from which they differ in the shorter, stronger uncus, the even thicker and more robust harp, the shorter almost rectangular juxta, and especially the aedeagus, which is shorter than in *creptricula* Tr. and whose central cornutus is massive and robust, not small and fine as in *ravula* Hb. (Pl. III, fig. 21), and not thin and elongated as in *ereptricula* Tr. (Pl. III, fig. 22). On the other hand, the little teeth, covering the discal sclerotised plates, are less strong than in *ereptricula* Tr., and the plates themselves are different in form and extent.

(8) Cf. Boursin in *Zeitschr. f. Lepidopterologie*, Bd. I, 2, 1952, p. 66.

Expanse : ♂, 28 mm. ; ♀, 26 mm.

Holotype : 1 ♂, Koragbal, 23.vi. 1942 (Coll. E.P. Wiltshire) ; Allotype : 1 ♀, Srinagar, 27.vi.1942 (Coll. E.P. Wiltshire).

Affinities : This new species should be placed immediately next to *Cr. creptricula* Tr., from which it is distinguished not only by the genitalia, as described above, but also by its more uniform grey appearance and by the pattern which rather resembles that of *Cr. ravula* Hb., and by the longer and narrower forewing shape. It is doubtless *Cr. ravuloides* Brsn. which Hampson recorded under the name of *ravula* Hb. from the Kashmir (Dana, Mc Arthur) in Cat. Lep .Phal., VII, p. 640, 1908.

recorded under the name of *ravula* Hb. from the Kashmir (Dana, Mc Arthur) in Cat. Lep. Phal., VII, p. 640, 1908.

Cryphia literata Moore (Pl. III. fig. 24)

(*Proc. Zool. Soc.*, 1881, p. 331)

Bagtor-Taobat track (7500 ft. = 2287 m.), 16,.vi.1942, 1 ♂.

This type of large *Cryphia* confined to the Himalayan Range and South-Western China, presents the same type of ♂ Genitalia as the *ravula* Hb.-group and is only distinguishable by a greater development of the harp.

Himalayan-SW. China.

Cryphia modesta Moore (Pl. IV, fig. 25)

(*Proc. Zool. Soc.*, 1881, p. 332)

Below Tragbal (6000 ft. = 1829 m.), 24.vi.1942, 1 ♂.

This species as in the case especially with the new species described hereafter and the *Cr. pulverulenta* Brsn. (from Spiti) and probably others of the Himalayan Chain, show a special type of genitalia amongst *Cryphia*, which is characterized by the narrowness of the valves, which gradually thin off towards the extremity, the absence of the Cucullus and Corona but more particularly by the very marked difference between the anterior and posterior parts of the valva, the first being strongly sclerotised and the other membranous, and in addition the great development of the harp, long and slender, curved in the form of a crook. This group could form a separate sub-genus.

Himalayan.

Cryphia wiltshirei n. sp. (Pl. I, fig. 4)

♂ : Antenna, very finely ciliated, the length of the ciliation not quite as great as the diameter of the shaft. Palp, with light brown scales, the third segment clearly projecting beyond the frons. Frons flat and smooth,

covered with long cream scaly hairs. Vertex, collar, patagia and thorax covered with cream scales mixed with some brownish ones. The metathorax carries a thick tuft of adpressed brownish and whitish scales, abruptly truncated distally. Abdomen, with a strong similar crest of scales on the first segment and other smaller crests on the following segments. Forewing, ground-colour cream, on which the transverse markings stand out deep blue-black. Basal area, powdered with blue-black ; basal line, well marked ; ante-median line, equally so, composed of saw-teeth and broadly white-edged proximally ; the whole discal area of a deep blue-black contrasting strongly with the ground-colour ; claviform stigma, absent ; orbicular stigma, comparatively large, slightly oblique white-rimmed, clearly defined ; the reniform stigma, on the other hand, is but slightly indicated by a fine blue-black transverse line ; post-median line, double, very clear, underlined with white, very denticulate and wavy, jutting far towards the termen but returning to the hind-margin with a sharp angle near the base ; postmedian area, of a cream colour, powdered with blue-black scales which are thicker towards the costa and form there a large ante-apical spot ; subterminal line, well-marked ; termen, formed of a series of little blackish interrupted dashes ; fringe, alternating cream and brown. Hindwing, of a dirty brown, with the discal spot and postmedian line well-marked in fuscous ; fringe, very long, brownish-yellow. Underside forewing of a dirty brown, with the discal spot and the postmedian line well-marked ; the nervures indicated in fuscous between the postmedian line and termen. Underside hindwing, like underside forewing, the discal spot and postmedian line being even more strongly marked. Expanse : 33 mm.

Holotype : 1 ♂, Kanzalwan (7645 ft. = 2330 m.), 15.vi.1942. (Coll. E.P. Wiltshire).

Genitalia of the male (Pl. IV, fig. 26) : Uncus, well-developed, slightly obtuse at the tip. Valves, relatively short and very wide at the base, narrowing abruptly after the sacculus and ending in a rounded lobe without cucullus or corona ; the part of the valve after the sacculus is divided longitudinally into two distinct parts, the costal border being very chitinised and the ventral border membranous ; harp, strong and short, curved outwards. Juxta, of irregular lozenge form. Saccus, normal. Aedeagus, robust, relatively short and large ; the vesica contains one strong cornutus and some fine chitinous granulation only.

The Genitalia characters show this species to belong to the group of *Cr. modesta* Moore (Pl. IV, fig. 25) and *Cr. pulverulenta* Brsn. (genitalia illustrated in *Revue Fse. d'Entomologie,* X, 1943, pl. VI, fig. 6). This group, as already stated, might constitute a special group (? Sub-Genus) among the *Cryphias* if it should prove to be really homogeneous and apart from the neighbouring species.

Affinities : I place this species provisionally next to *Cr. modesta* Moore from which its markings and genitalia clearly distinguish it.

Himalayan.

ZENOBIINAE

Euplexia semifascia Wlk. (Pl. III, fig. 20)

(XXXIII, 737, 1865)

Tragbal, 1 ♂, 24.vi.1942.

The genitalia of this species have a double uncus, but the other parts of the armature are of similar type to *Eupl. lucipara* L. of which the uncus is also splited, so much so that this pecularity must only be considered as a polyphyletic character, being capable of appearing in any genus and not affecting the other parts of the genitalia, which remain characteristic of the genus. The double or bifurcate uncus, which is the rule in certain groups of Heterocera (for instance in the *Zygaenidae*, very frequent in the *Attacidae*, and trifurcate in the *Tethcidae* (*Cymatophoridae*) appears only incidentally in the *Trifinae*, for instance in the genus *Allophyes* Tams and *Eicomorpha* Stgr. (bifid), in *Cirrhia lutea* Strom, *Spudaea ruticilla* Esp. (double) and in a recently described new *Agrotinae*-genus from Patagonia, *Euxoamorpha* Frclt., with the new species *eschata* Frclt.

Subtropical-oriental.

Trachea melanospila Kollar

(Hügel's Kaschmir, IV, p. 480, 1844)

Badwan Gurais, 20.vi.1942, 1 ♀.

Himalayan, goes towards North-China.

Caradrina (Paradrina) himaleyica Kollar

(Hügel's Kaschmir, IV, p. 479, 1844 ; *Car. arenacea* Moore, *P.Z.S.*, 1881, p. 349 ; *Caradr. chinensis* Leech, *Trans. ent. Soc.*, 1900, p. 117)

Kanzalwan, 10.vi.1942, 1 specimen ; Koragbal, 23.vi.1942, 1 specimen.

Very common species in the Himalayan Chain, especially towards the East.

Himalayan, extending as far as China.

Mesotrosta ignobilis n. sp. (Pl. I, fig. 10)

♀ : Antenna, finely ciliated. Palpi covered with brown scales. Frons, with a fairly strong granular rounded prominence, covered with brown adpressed scales. Vertex, covered with a mixture of brown and yellowish scales. Collar, clad with large yellowish scales mixed with brown. Thorax (rubbed). Abdomen, yellowish, without visible crests, the specimen being rubbed. Fore-

wing, uniformly dark-brown, with the transverse lines appearing darker. Basal line, indistinct (rubbed) ; antemedian, median shade, postmedian, and subterminal, well-defined in blackish brown ; claviform stigma, absent ; orbicular, visible, in the form of a small blackish brown point ; reniform, indistinct ; fringe, concolorous. Hindwing, uniformly blackish brown, unmarked ; fringe, long, yellow-brown. Forewing underside, of a dirty grey brown, with postmedian line strongly indicated at the costa, underlined with paler ; a narrow terminal band, lighter than the ground colour. Hindwing underside, of the same colour as the forewing upperside, the termen being darkened by a broad brown band which reaches as far as the postmedian. Discal spot slightly indicated.

Expanse : 23 mm.

Genitalia of the male (Pl. IV, fig. 30) : Uncus, relatively long, and slightly wider towards the end. Valve, relatively long and narrow, with borders almost parallel, slightly wider distally, the end being rounded regularly and bearing neither cucullus nor corona but only a few hairs. The anterior border, at the base of the valve, extends curiously towards the juxta, in a kind of narrow appendix forming a right angled hook turned upwards and apparently forming a process analogous to a superior clavus. The harp consists of a finger-shaped, fairly long appendix, rounded at the end. Juxta, large and well-developed, in the form of an inverted battle-dore, whose base is represented by a very large rounded plate and whose upper part (the handle of the battle-dore) is very long and more chitinised. Saccus, short and rounded. Aedaeagus, relatively long and well-developed, slightly curved dorso-ventrally, the vesica being armed with a central mass of comparatively short cornuti, and the external distal part (sinus penis) is distinctly more chitinised than the rest of the aedaeagus.

Holotype : 1♂, Kanzalwan, 14.vi.1942 (Coll. E.P. Wiltshire).

Affinities : This species, which superficially resembles a *Hadjina*, must be placed in the genus *Mesotrosta* Led. on account of the rounded frontal prominence, the genus *Hadjina* having the frons flat and smooth, and on account of the general form of the genitalia. These approach those of *M. signalis* Tr. (Pl. IV, fig. 29), in the uncus-form, in the juxta, and particularly in the aedeagus, which has more or less the same constitution. The valves are also similar. The upper border at the base in *signalis* Tr. presenting the same peculiar process described above, but much less accentuated and sclerotised. The harp has roughly the same appearance, but the extension of the sacculus, present in *signalis* Tr., is here not developed.

? Kashmir endemic. Probably of Central-Asian origin. (9).

(9) Werneburg (II, p. 219, 1864) treats *Mes. signalis* Tr. 1825 as synonym of « *Bombyx* » *punctum album* de Villers (*Entom. Linn.*, II, p. 175, 1789). As *Mes. signalis* Tr. does not occur in France there must certainly be a mistake and

Busseola hirsuta n. sp. (Pl. 1, fig. 7)

♂ : Antenna, with a fairly strong shaft very slightly moniliform (i.e. with segments slightly swollen), and with very short ciliation. Palp, slender, covered with long and rough brownish hairs, the third segment projecting distinctly before the frons. Frons, smooth and glossy, slightly domed, covered with long rough brownish hairs. Vertex, collar, patagia and thorax equally covered with very long and rough brownish hair-like scales. Metathorax with a tuft of adpressed hairs. Abdomen, with a crest of scaly hairs on the first segment. Forewing, dirty yellow-brown, with the transverse lines standing out dark brown. Basal line, indistinct ; claviform stigma, absent ; a long brownish shade in the submedian fold extending to about the postmedian line ; the antemedian line, well-marked, dark, very oblique ; median shade, very faint ; orbicular and reniform stigmata indistinct, the space between them being rusty-coloured ; postmedian line, well-marked, dark, very oblique, joining the antemedian line on the hind margin and forming with it an obtuse angle ; median area concolorous ; subterminal line, only visible above the tornus ; very oblique, but well-marked and dark ; the terminal area above the tornus paler than the rest of the wing ; terminal line, consisting of a series of little dashes between the nervures ; fringe, brownish, with paler interruptions. Hindwing, uniformly dark brown, the fringe slightly paler. Underside forewing, dirty brown, the terminal part paler, not distinctly marked. Underside hindwing, like the upperside, with only a slight indication of the postmedian line.

Expanse : 22 mm.

Holotype : 1 ♂, Taobat, Kishenganga Valley (7400 ft. = 2255 m.), 16.vi.1942 (Coll. E.P. Wiltshire).

Genitalia of the male (Pl. IV. fig. 28) : Uncus, short and thick, ending in a point. Valves, short and wide, the inferior process very developed and covering more than half of the valve ; it is strongly curved proximally towards the costa at the base, and forms in the middle of the valve an obtuse lobe projecting beyond the costa : the outer border of the inferior process is abruptly truncated transversely and comes down to the ventral border of the valve, where it ends in a chitinous point projecting strongly towards the valve-tip ; the valve-tip itself is very slightly chitinous, rather membranous, rounded, without cucullus or corona and with only a few terminal bristles and hairs ; harp, consisting of a large strongly chitinous rounded button,

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very probably confusion with a form of *Apamea secalis* L. This appears to be proved by the figure of *N. leucostigma* Esper. (pl. 159, fig. 7) which was made from a specimen received from de Villers under the name of *punctum album* and is clearly only a form of *Apamea secalis* L. which is very widely spread in the South of France. It is difficult to understand how Werneburg can apply this figure of Esper to *signalis* Tr. (see Werneburg, II, p. 48).

short and strong, like that to be seen in *Pseudocopicucullia syrtana* Mab. and *biskrana* Ob. Juxta, well-developed, roughly cordiform, with two divergent lateral blades, long and narrow, pointed at their extremities and with some adpressed chitinous teeth, the anterior border of these blades strongly sclerotised and scobinated. This formation is close to that seen in some *Geometridae,* e.g. *Gnophos intermedia* Wehrli ([10]). Saccus, short and wide. Aedeagus, of normal size, equipped with only one strong cornutus ending in two very chitinous points.

Affinities : I place this species provisionally beside *Busseola* (*Calamistis* Hps.) *submarginalis* Hps. from Madras. It is clearly a subtropical element probably of Gondwanian origin, which has come from the plains of India.

HELIOTHIDINAE

Chloridea obsoleta F.

(*Ent. Syst.,* 3, 1, *p.* 456, 1793)

Taobat, 16.vi.1942, 1 specimen.

Cosmopolitan.

ACKNOWLEDGMENT

I am much indebted to Mr. Anastase Alfieri, General Secretary of the Société Fouad Ier d'Entomologie, Cairo, for many kindness as to the publication of the present paper. I would sincerely thank Mr. W. H. T. Tams for having so carefully examined certain Types for me and for his very valuable assistance, and that of Messrs. H. Gallay and Lespès, for the splendid microphotographs illustrating the present article.

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([10]) See Warnecke : « Zur Kenntnis von *Gnophos intermedia* Wehrli », in *Iris,* LV, 1942, p. 25, fig. 2. The lobes, shaped like saw-blades, here have wrongly stuck to the aedeagus and belong in reality to the superior part of the juxta.

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PLATE I

Explanation of Plate I

Fig. 1 : *Ochropleura herculea* Cti.-Drdt., ♀, Kanzalwan.

Fig. 2 : *Diarsia stictica viaria* Swinh., ♀, Tragbal.

Fig. 3 : *D. stictica viaria semipleta* Warren, ♀, Kanzalwan.

Fig. 4 : *Cryphia wiltshirei* Brsn., ♂, Holotype, Kanzalwan.

Fig. 5 : *Cryphia ravuloides* Brsn., ♂, Holotype, Koragbal.

Fig. 6 : *Cryphia ravuloides* Brsn., ♀, Allotype, Srinagar.

Fig. 7 : *Busseola hirsuta* Brsn., ♂, Holotype, Taobat.

Fig. 8 : *Mythimna mesotrosta kashmirensis* Brsn., ♀, Holotype, Pir Panjal.

Fig. 9 : *Mesotrosta signalis* Tr., ♀, Vienna.

Fig. 10 : *Mesotrosta ignobilis* Brsn., ♂, Holotype, Kanzalwan.

Fig. 11 : Male genital armature of *Ochropleura herculea* Cti.-Drdt., Spiti (x 10).

Fig. 12 : Male genital armature of *Agrotis duosigna* Hps., Kanzalwan (x 10).

Fig. 13 : Male genital armature of *Ochropl. flammatra* Schiff., France (x 10).

Fig. 14 : Male genital armature of *Diarsia stictica* Pouj., Type! Mou-pin (x 10).

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PLATE II

Explanation of Plate II

Male genital armatures (x 10) of :

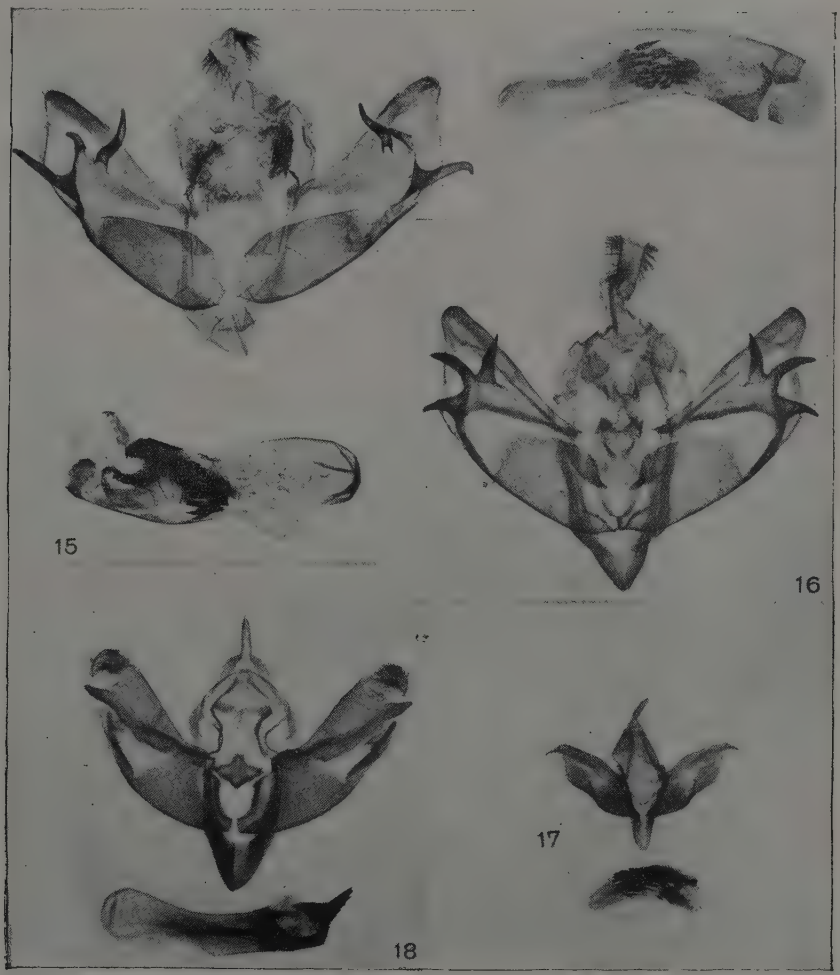
Fig. 15 : *Bryopolia virescens* Hps., Badwan Gurais.

Fig. 16 : *Bryopolia chrysospora* Brsn., Holotype, Zarafshan (Russian Turkestan).

Fig. 17 : *Byromima carducha* Stgr., Iran.

Fig. 18 : *Eumichtis variabile* Stertz, Algeria.

Charles Boursin Plate II



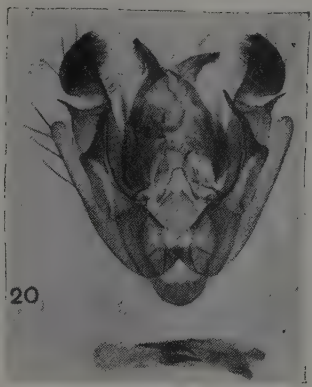
Gallay phot.

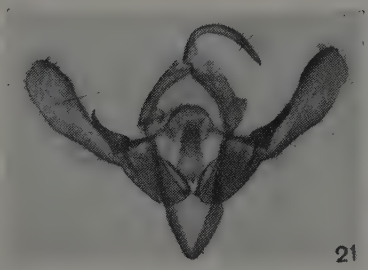
PLATE III

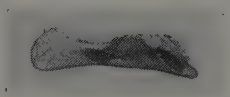
Explanation of Plate III

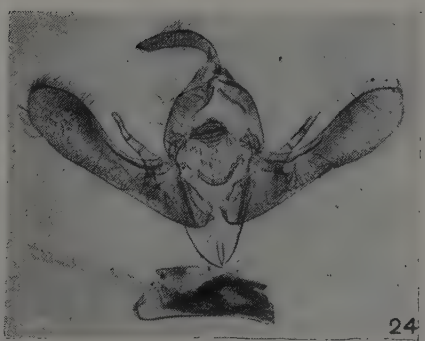
Male genital armatures of :

Fig. 19 : *Dasythorax poliana* Stgr., Kizil-Yart (Russ. Turkestan) (x 10).
Fig. 20 : *Euplexia semifascia* Wlk., Tragbal (x 10).
Fig. 21 : *Cryphia ravula* Hb., France (x 17).
Fig. 22 : *Cryphia creptricula* Tr., Lake Ochrida (Macedonia) (x 17).
Fig. 23 : *Cryphia ravuloides* Brsn., Holotype Koragbal (x 17).
Fig. 24 : *Cryphia literata* Moore, Bagtor-Taobat (x 17).









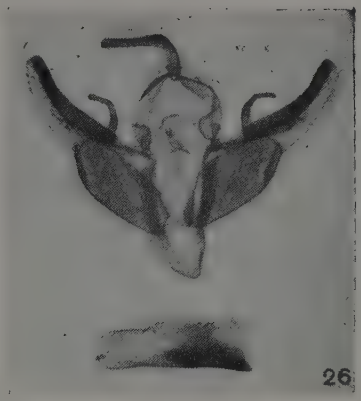
Gallay and Lespès phot.

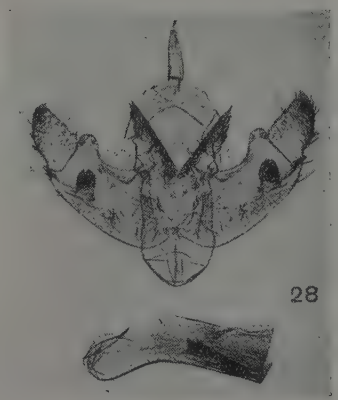
PLATE IV

Explanation of Plate IV

Male genital armatures of :

Fig. 25 : *Cryphia modesta* Moore, Tragbal (x 17).
Fig. 26 : *Cryphia wiltshirei* Brsn., Holotype, Kanzalwan (x 17).
Fig. 27 : *Apatele gastridia* Swinh., Koragbal (x 10).
Fig. 28 : *Busseola hirsuta* Brsn., Holotype, Taobat (x 17).
Fig. 29 : *Mesotrosta signalis* Tr., Vienna (x 17).
Fig. 30 : *Mesotrosta ignobilis* Brsn., Holotype, Kanzalwan (x 17).





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Revision of species of the genus *Acrida* Linné

[Orthoptera, Acrididae]
(with 22 Text-Figures and 8 Maps)

by V. M. Dirsh, D.Sc.
Anti-Locust Research Centre, London.

INTRODUCTION

Almost all specific characters in the genus *Acrida* have only relative significance and each character may be described by comparison with the same one of other species only by the words « more » or « less » ; every species has a large range of variation, even in the same locality ; and every species has many local races. All this creates many taxonomic difficulties. The general impression is that species in this genus are not yet stabilised and distinctions between them are not so sharp as between species of other genera.

In 1949 (Dirsh, *Eos,* XXV) an attempt was made to revise the West Palaearctic species of the genus. Now, having studied about four thousand specimens of almost all known species, I have come to the conclusion that it is necessary to treat species of *Acrida* in broader limits than was done in my previous work and in the works of other authors. In treating species in this way there is a danger of confusing some which are closely similar but, at the present stage of our knowledge of the genus, this is better than the establishment of numerous species, which are difficult to differentiate. In accordance with this point of view, in this work only such characters have been adopted as allow a differentiation of species without complicated measurements. All subspecies previously described are temporarily disregarded, because all taxonomic units below the species need revision, further bio-ecological investigation and statistical treatment.

Some of the synonyms for the species and subspecies as suggested below may later prove to apply to lower taxonomic categories.

Even with this broader conception of species, their precise determination will be sometimes difficult and the best results will be obtained by using the serial material and comparing it with already known species.

For this work the material used was from the British Museum ; (large material of Dr. E. Burtt from Tanganyika and of Mr. H. B. Johnston from Nigeria, Sudan and Uganda ; material from Mr. O. B. Lean from Nigeria) ; the Paris Museum ; Belgian Congo Museum, Tervueren ; Coryndon Museum, Nairobi ; S. Australian Museum ; private collections of Dr. Willemse, Holland and Mr. Whellan, S. Rohdesia; and many small collections from different persons and countries

I am greatly indebted to all concerned with providing this material and particularly to the persons who provided types for examination.

The method of revision adopted in this work was as follows : the whole material of the genus was studied and divided into species without naming them ; then each species was compared with the types and the descriptions. Almost all existing types were studied.

The types of Thunberg's species preserved in the Uppsala Museum presented the most difficulties. All of them are about 175 years old, in poor condition and without any locality labels. A most careful study was necessary to decide to what species each type corresponded. The type of each of the existing Thunberg's species has been fixed and the species represented in the British Museum by a most closely corresponding specimen.

Some of those species, the types of which are lost, have sufficient descriptions or geographical criterial, by which they may be identified. The types of *A. gigantea* Herbst and *A. dentata* Thunberg are lost, their descriptions are insufficient and their localities are unknown, therefore their identity remains problematic.

HISTORICAL NOTE ON THE GENUS

In 1758 (Syst .Nat. ed. X : 427, no. 12) Linné described *Gryllus* (*Acrida*) *turritus* with « Alis hyalinis » and *Gryllus* (*Acrida*) *nasutus* with « Alis sanguinolentis ».

Fabricius in 1775 (Syst. Ent.: 279) used the new name *Truxalis* for these two species. Most of the later authors adopted this name, sometimes changing its transcription and, in most casses, confusing the two species *turritus* and *nasutus*. Only in 1910, Kirby (Syn. Cat. Orth.: 90) fixed the genotype of the genus *Acrida* Linné as *Acrida turrita* Linné. The genotype *Truxalis nasutus* (Linné) of the genus *Truxalis* Fabricius was formally fixed by Radclyffe-Roberts in 1941 (*Trans. Amer. Ent. Soc.,* LXVIII: 20). Fuller history of the formal relations between the genera *Acrida* and *Truxalis* and their genotypes will be found elsewhere (Dirsh, 1950, *Eos*).

POSITION OF THE GENUS

The genus *Acrida* L. belongs to the tribe *Acridini* (see Dirsh, 1950),

which is characterised by the absence of stridulatory pegs on the internal side of the hind femur and the presence (in most cases) of more or less developed vena intercalata of the elytra.

Acrida has only two related genera *Chromacrida* Dirsh (1952, *Proc. R. Ent. Soc. Lond.*, B., XXI, parts 9-10, pp. 135-139) with the genotype *Chromacrida radamae* (Saussure, 1899) and *Brachyacrida* Dirsh (*l.c.* 1952) with the genotype *Brachyacrida distanti* Dirsh (l.c. 1952).

All three genera are well differentiated from one another, and form a rather isolated group within the tribe *Acridini.*

GENERIC GROUP ACRIDAE

Body strongly elongated, cylindrical ; head strongly elongated, acutely conical ; antenna flattened and broadened, tapering to the apex ; eyes near the apical part of the head ; hind femur long and very narrow ; hind knee with acute lobes on both sides.

KEY TO THE GENERA

1 (4) Wing with speculum, colourless or uniformly coloured, without pattern.

2 (3) Disc of pronotum flat or weakly tectiform. Elytra with pointed, acute, or obtuse apex. ..... **ACRIDA**

3 (2) Disc of pronotum saddle-shaped. Elytra with rounded apex. .... **BRACHYACRIDA**

4 (1) Wing without speculum, brightly coloured, with red fascia and dark brown external margin. ..... **CHROMACRIDA**

SPECIFIC CHARACTERS

(1) Head : For most of the species the shape of the head is one of the best characters, particularly as regards its length and width in the basal part. This is the most useful character in differentiating the species and even some species groups. In some species, e.g. *Acrida turrita*, the head is acutely conical with the frons almost straight in profile. In other species the head is conical, but less acute, less narrow, with the frons incurved in profile. Shape of fastigium of vertex and its relative measurements may be useful for subspecies and smaller taxonomic units.

(2) Antennae : Only the shape of the antenna has specific significance. The shape and incomplete separation of the basal segments is not a stable character in a large series from different localities.

(3) Pronotum : The shape of the lateral carina of the pronotum

and of its disc are sometimes good specific characters, but in most species these characters vary enormously.

(4) Elytra: The form of elytra is the most important specific character, which varies insignificantly and may be useful also as a character for some groups of species.

(5) Subgenital plate: The male subgenital plate is significant for some species, but for most species this character is of little value.

(6) Body: Size of body varies enormously; in some species the difference can be up to a hundred per cent.

(7) Colouration: Old authors used colour characters in their description. Actually there are only few types of colouration, and they are repeated in all species. One type may be dominant in one locality, but in a long series all types are found. It would appear that the colouration depends, to a great extent, on the environment. This has already been confirmed experimentally (Ergene, 1950, *Zeit. Vergl. Physiol,* XXXII: 530).

Three main types of coloration can be distinguished: pure green (darker in northern species, lighter in more southern ones); straw-yellow; and dark-grey to brownish, sometimes with faint small dark streaks.

Individuals of any of the three kinds may be uniformly coloured, or have a pattern consisting mainly of longitudinal stripes. Along the middle of elytra, through the discoidal area, there often runs a dark stripe, which may be interrupted by short oblique light streaks. Sometimes this stripe becomes so wide that the whole elytron is dark, with light margins. Less frequent are individuals with a light-yellowish or pinkish stripe along the axillary area of the elytron. Lateral pronotal carinae may be light, or there are light stripes either on their outer, or the inner, side. Pronotal disc may have two dark stripes. Sides of the head sometimes have light or dark, or both light and dark, stripes. All these elements of the pattern may occur in various combinations.

The colouration of the wings is sometimes the best specific character, which varies only during sexual maturation.

VARIABILITY OF SPECIES OF ACRIDA

Species of the genus *Acrida* have an enormous range of variation and often two specimens differ one from another so strongly that they may be regarded as quite different species. Only the study of large series allows the establishment of the presence of all intermediate forms.

There are the following kinds of variability in species of this genus:

(1) Geographical variability: This type of variability, usually adopted for separating subspecies, is more definite than others, but

after studying a large amount of material, it was found that every such subspecies may be divided into many others of equivalent or smaller subspecies or local races Almost every locality has its local race which may be differentiated by the descriptive or the biometrical method. However, sometimes it is difficult to decide whether such races are the result of geographical isolation, or due to ecological conditions, or to a combination of both.

(2) Ecological variability : Sometimes this type of variability is very great and it is difficult to separate it from the first type of variability. Specimens from dry and wet places, from mountains and from lowlands differ greatly in their morphological characters, and all intermediate forms exist.

(3) Seasonal variability : In tropical regions species of *Acrida* are found all the year round and produce two and possibly more annual generations. The generations of the dry and the rainy season may differ strongly from one another in the size of body.

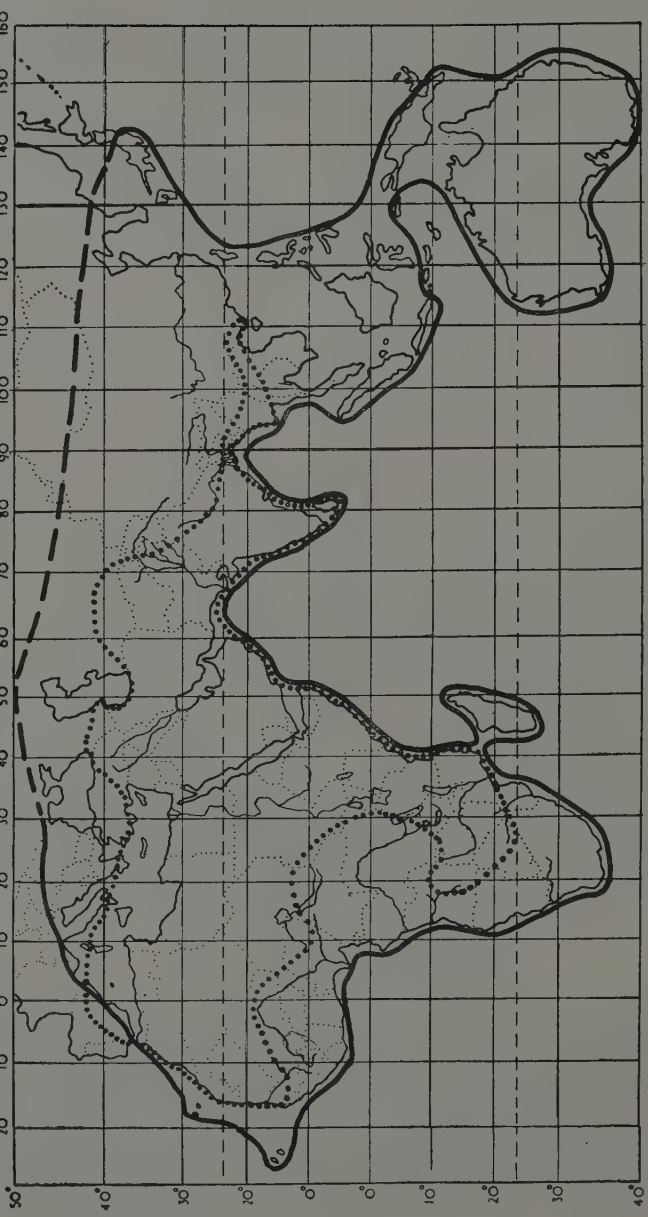
(4) Individual variability : This variability is sometimes very great ; specimens from the same population sometimes differ strongly from one another.

(5) In many cases copulation of the male and female of different species was observed and the possibility of hybridisation between species is not excluded. Copulation was observed between : ♂ *A. bicolor* × ♀ *A. acuminata* ; ♂ *A. bicolor* × ♀ *A. sulphuripennis* ; ♂ *A. confusa* × ♀ *A. bicolor*. Even copulation between representatives of two different genera was observed : ♂ *Truxalis burtti* × ♀ *Acrida bicolor*. These data are given on the basis of Dr. E. Burtt's material from Tanganyika and H. B. Johnston's from Uganda.

In such conditions of variability, a description of the type is not very useful for understanding the species as a whole, but it is still necessary in case other investigators should divide a species into smaller ones. In this work the description of the type is given, and if no type exists, the description is given from specimens from the typical locality.

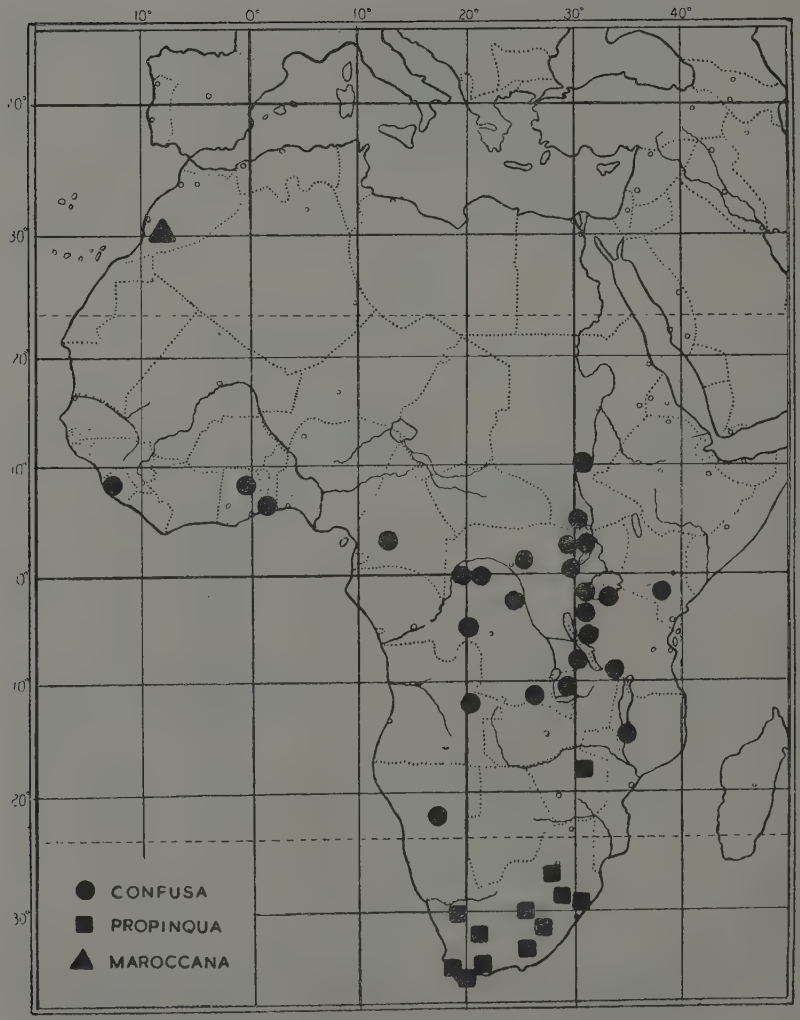
BIOGEOGRAPHY OF THE GENUS

The genus *Acrida* occurs throughout Africa, Canary Islands, Cape Verde Islands, Madagascar, the southern part of Europe and all the Mediterranean islands, throughout the southern half of Asia (where its northern limit follows roughly the annual isotherm + 8° C.), Japan, Australia and the Australasian Archipelago (see Map 1). There are no records from Borneo, but since the genus occurs in all the neighbouring islands, it will probably be found in Borneo also. Some species of the genus are also broadly distributed within the generic area (see Maps 2-8). Since *Acrida* are poor fliers, this

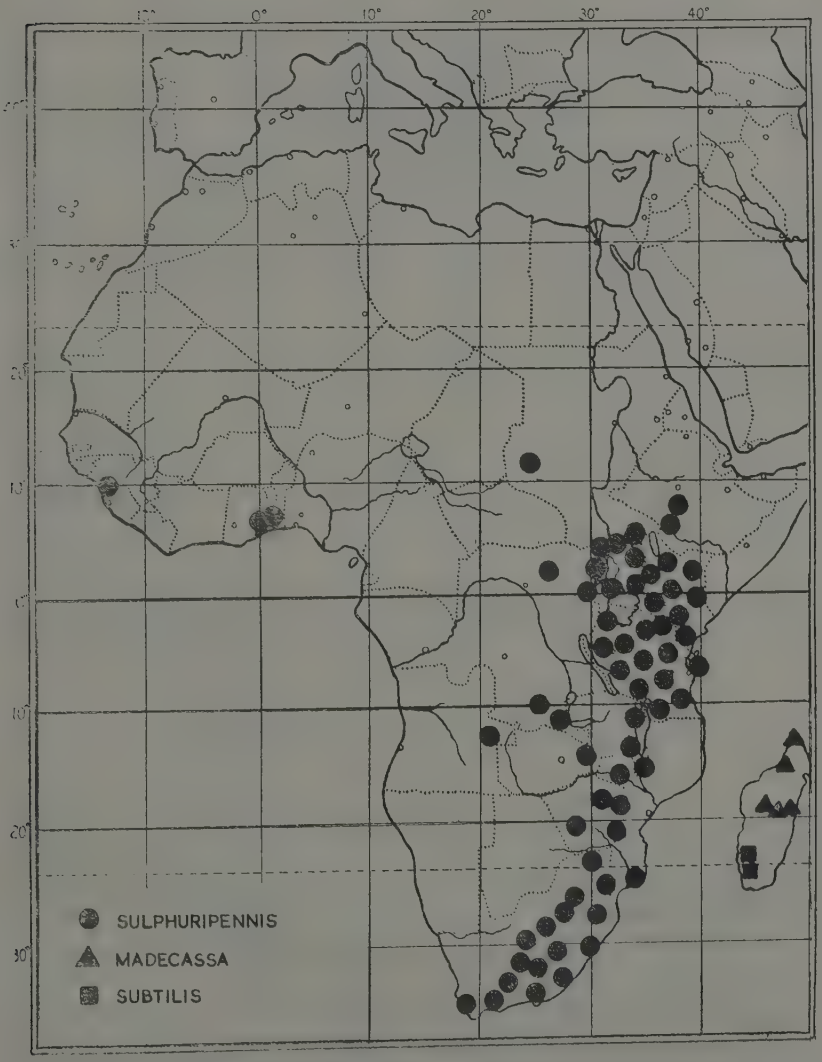


Map 1. — Area of the genus *Acrida* (solid line) ; area of the genus *Truxalis* (dotted line).

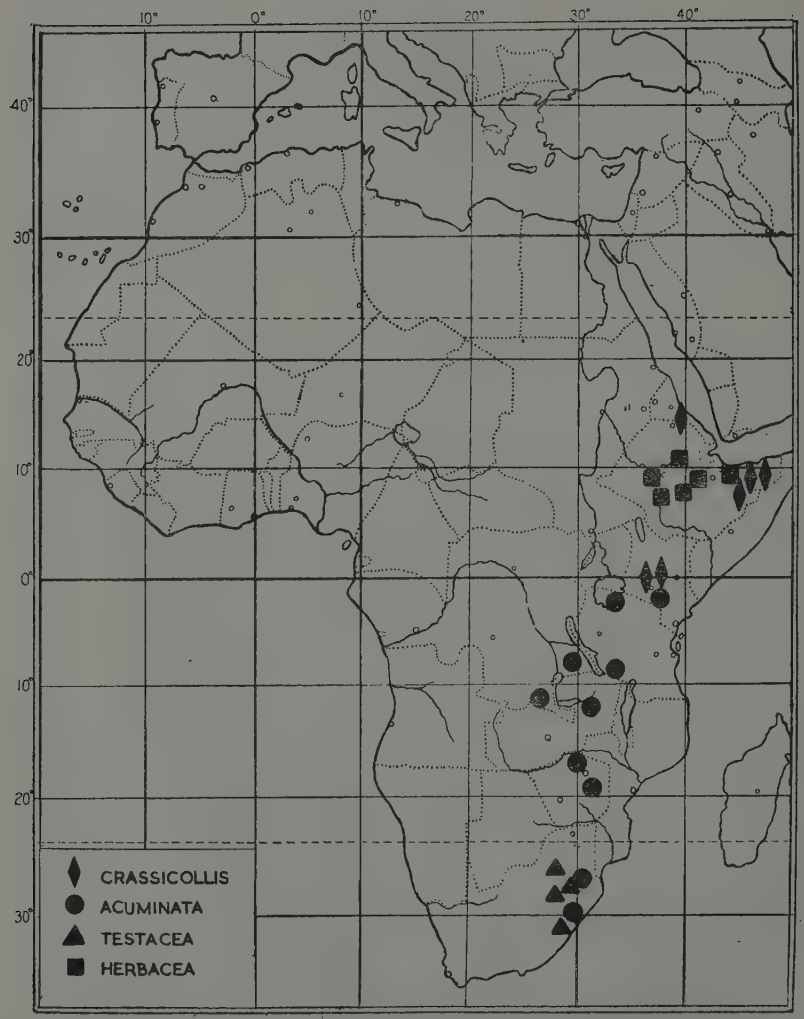
Map 2. — Distribution of *Acrida turrita*.



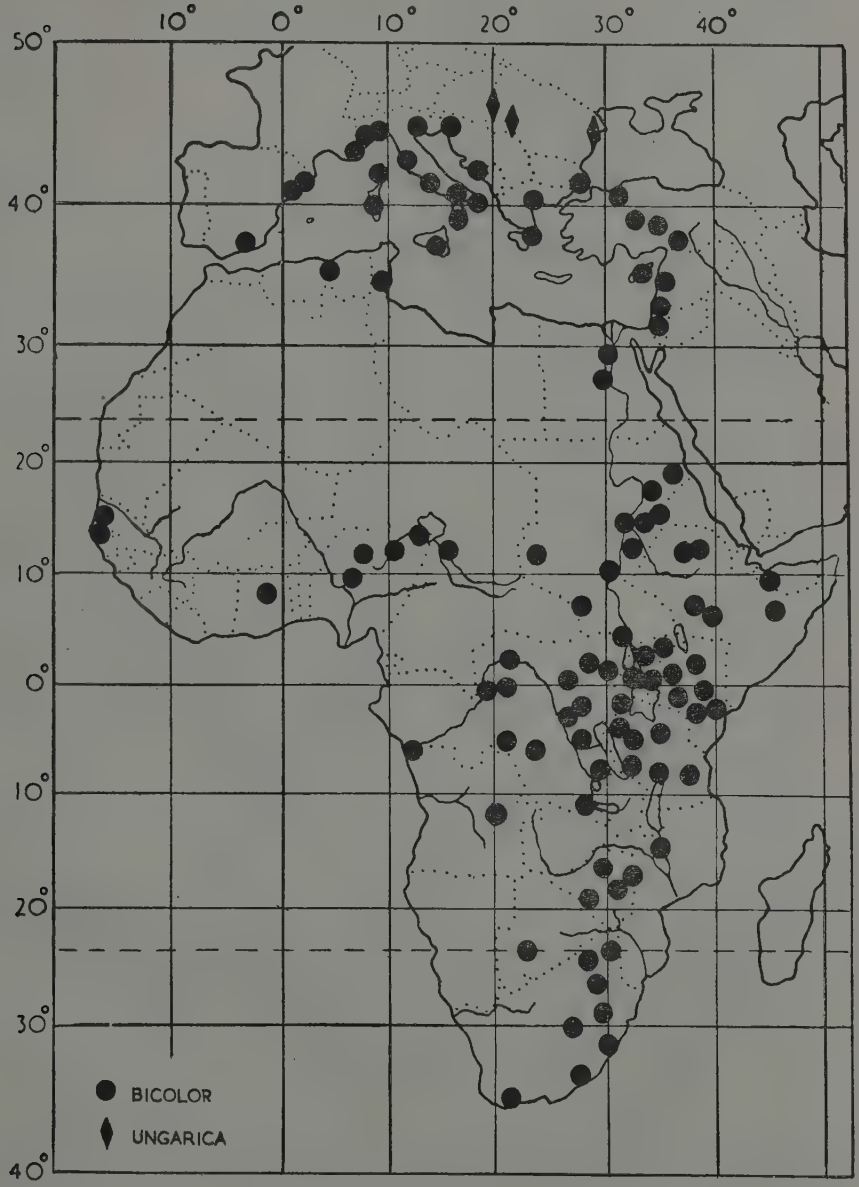
Map 3. — Distribution of : *Acrida maroccana, confusa* and *propinqua.*



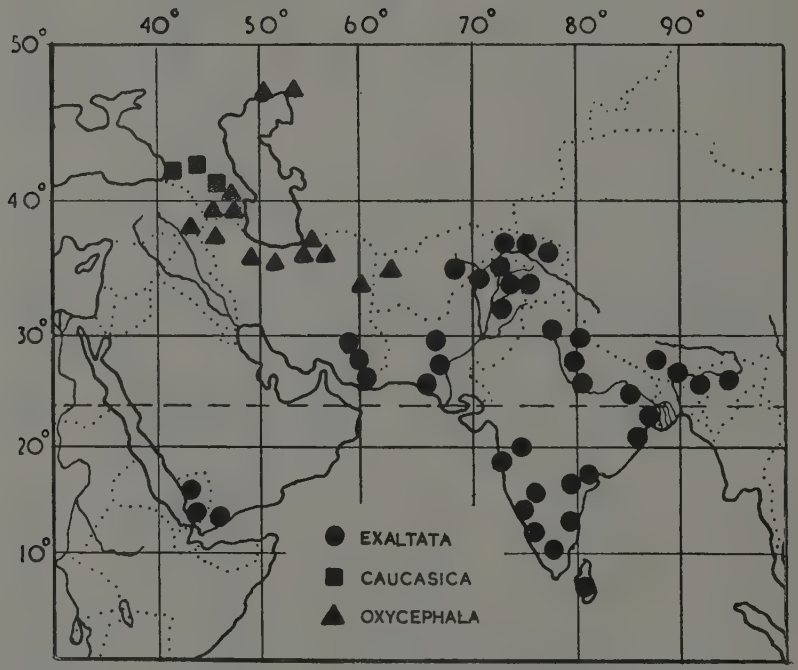
Map 4. — Distribution of : *Acrida sulphuripennis, madecassa* and *subtilis.*



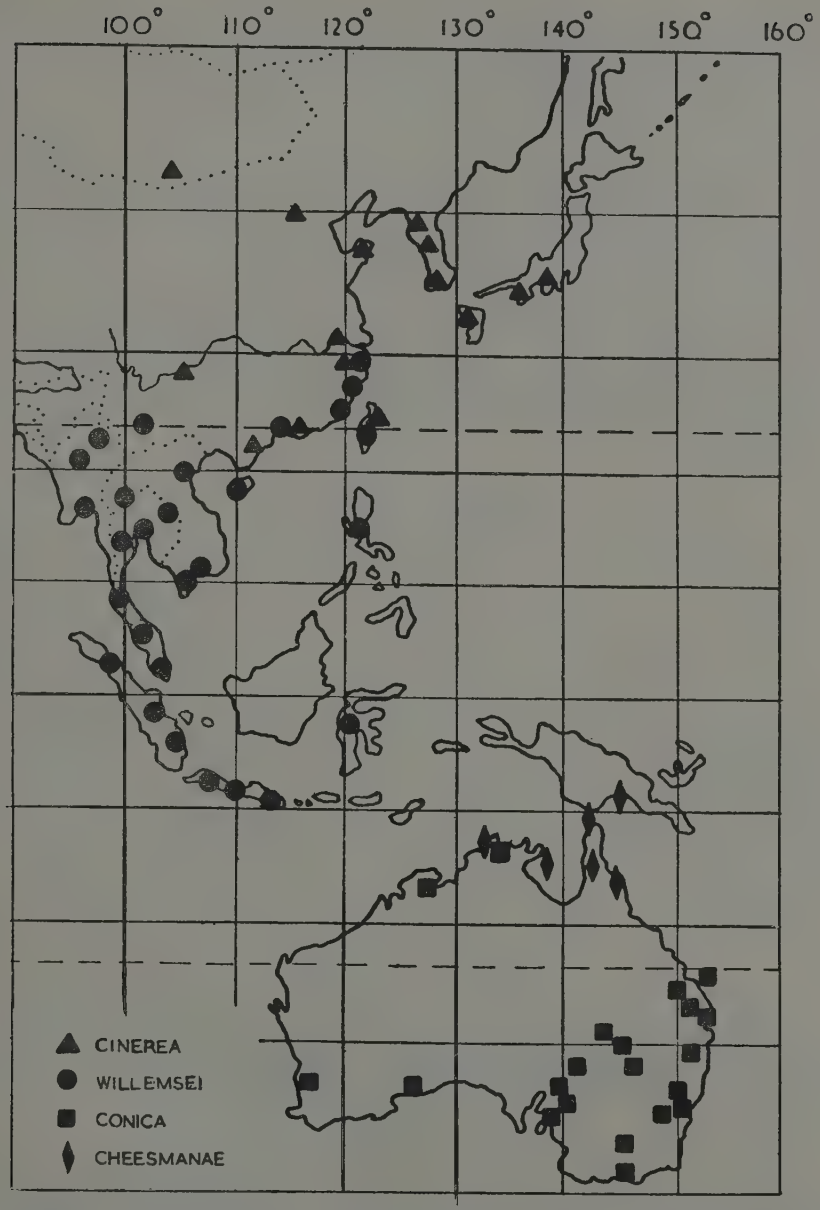
Map 5. — Distribution of : *Acrida acuminata, crassicollis, herbacea* and *testacea.*



Map 6. — Distribution of : *Acrida bicolor* and *ungarica*.



Map 7. — Distribution of : *Acrida exaltata, oxycephala* and *caucasica.*



Map 8. — Distribution of : *Acrida cinerea, willemsei, cheesmanae* and *A. conica.*

indicates that the genus existed at times when Madagascar and Cape Verde and Canary Islands were connected with the African continent and Japan, Australasian Archipelago and Australia were connected with Asia. If the distribution areas of *Acrida* and *Truxalis* are compared (Map 1, the distribution of *Truxalis* is given according to the latest data), it will be seen that the range of *Truxalis* is limited to the African and Asian continents, and is much smaller than that of *Acrida*. This suggests that the genus *Acrida* was developed much earlier when it was able to spread over an enormous area, while *Truxalis* must have developed later when the islands inhabited by *Acrida* and Australia were disconnected from Africa and Asia.

Geological records of the time of these connections are uncertain and do not make it possible to establish the time of expansion of the genus. However, a study of the ecological habits and morphological characters, may indirectly help to suggest the probable time of development and distribution of the genus.

In this respect the genus *Acrida* is analogous with the genus *Truxalis* (see Dirsh, 1950, *Eos*). *Acrida* is ecologically connected with grasslands of every type from dry to relatively wet. In this respect it has broader limits of ecological adaptation than *Truxalis*, particularly in the wet range. The body structure of *Acrida*, like that of *Truxalis* indicates that its adaptation to grasslands is an ancient one (see Dirsh, 1950 *l.c.*), and that the development and formation of the genus took place in the geological time when grasslands not only existed, but flourished, possibly during the Pliocene to the Pleistocene period. At the present time some species of *Acrida* are distributed in forest zones also, but even in this case they remain connected with grass habitats.

On the other hand, the weakness of specific characters, the large number of species and great range of their variability, the presence of numerous local races and other lower taxonomic units suggest that *Acrida*, probably is a genus still in active process of development and formation of species.

GEN. ACRIDA LINNE

1758, *Gryllus* (*Acrida*) Linné, Syst. Nat., 10th ed. — 1775, *Truxalis* (partim) Fabricius, Syst. Ent. : 279. — 1835, *Tryxalis* (partim) Brullé, Hist. Nat. Ins., IX : 216. — 1846, *Troxallis* (partim) Fischer v. Wadheim, Orth. Ross., IV : 228. — 1873, *Acrida* (partim) Stäl, Rec. Orth : 104. — 1902, *Acrida* (partim) Burr. *Trans. Ent. Soc. Lond.*, II : 149. — 1910, *Acrida* (partim) *Kirby, Syn. Cat. Orth.*, III : 90.

Genotype: *Gryllus* (*Acrida*) *turritus* Linné 1758.

Body strongly elongated, ratio of length to maximal width 6.3-13.0.

Antenna flattened, broadened and gradually tapering to the apex. Head strongly elongated, conical. Fastigium of vertex large and strongly projecting in front of the eyes.

Pronotum long, disc flat or weakly tectiform with single transverse sulcus, median and lateral carinae low, but very distinct. Mesosternal interspace longer than broad (in the robust species almost as long as broad).

Elytron long and narrow, ratio of length to width 8.2-14.3, with strongly acute to obtuse apex. Wing with a well developed lustrous speculum, without any pattern.

Hind femur long and narrow, ratio of length to width 8.4-21.0. Lateral lobes of the hind knee acute, the upper internal lobe very slightly longer than the external ; median projection weak. Arolium moderately large ; shorter than a claw.

Male supra-anal plate triangular, simple. Cercus short, narrow, conical. Subgenital plate conical or acutely conical.

Female supra-anal plate obtusangulate. Subgenital plate weakly trilobate or almost truncate. Ovipositor short, robust, with broad, slightly curved, valves.

LIST OF SPECIES

1. *A. acuminata* St., Tropical and S. Africa ; 2. *A. turrita* L., Tropical, North Africa and Sicily ; 3. *A. maroccana* Dirsh, Morocco ; 4. *A. confusa* sp. n., Tropical Africa ; 5. *A. sulphuripennis* (Gerst.), S. and Tropical Africa ; 6. *A. propinqua* Burr, S. Africa ; 7. *A. herbacea* I. Bol., Ethiopia ; 8. *A. testacea* (Thunb.), S. Africa ; 9. *A. crassicollis* Chop., E. Africa ; 10. *A. bicolor* (Thunb.), Africa, Mediterranea ; 11. *A. ungarica* (Herbst.), S.E. Europe ; 12. *A. madecassa* (Brancs), Madagascar ; 13. *A. subtilis* Burr, Madagascar ; 14. *A. caucasica* Dirsh, Asia (Caucasus) ; 15. *A. oxycephala* (Pall.), S.W. Asia ; 16. *A. exaltata* (Walk.), S. Asia ; 17. *A. indica* sp. n., S. Asia ; 18. *A. lineata* (Thunb.), S. Asia ; 19. *A. cinerea* (Thunb.), S.E. Asia ; 20. *A. willemsei* sp. n., S. Asia, Malaya ; 21. *A. cheesmanae* sp. n., Papua, Australia ; 22. *A. conica* (F.), Australia ; 23. *A. carinulata* (I. Bol.), Cape Verde Is.

It is not known what species occurs on the Canary Islands, since only a series of nymphs is known from Gran Ganaria.

KEY TO SPECIES

1 (14) Transverse sulcus of pronotum behind the middle of pronotal disc (Figs. 1, 2, 3, 4, 7, 17, 21).

2 (11) Head strongly elongated, slender with narrow basal part (Figs. 1, 2, 3, 4, 21).

3 (4) Elytron very strongly elongated and narrowed ; wing very narrow, considerably shorter than elytron (Fig. 1), dull, semipellucid. Tropical and S. Africa. ..... **acuminata St.**

4 (3) Elytron less elongated and broader ; wing comparatively broader, insignificantly shorter than elytron (Figs. 2, 3, 4, 21) lustrous, pellucid.

5 (8) The projection on the upper margin of the male subgenital plate, in profile, comparatively small (Figs. 2, 21).

6 (7) Head relatively broad in the basal part ; fastigium of vertex relatively short. Pronotum relatively broad. Male subgenital plate, in profile, with a small rounded projection on the upper margin (Fig. 21). Papua-Australia. ..... **cheesmanae sp. n.**

7 (6) Head relatively narrow in the basal part ; fastigium of vertex relatively long. Pronotum relatively narrow. Male subgenital plate in profile, with a larger tooth-shaped projection on the upper margin (Fig. 2). Africa. ..... **turrita L.**

8 (5) The projection on the upper margin of the male subgenital plate, in profile, very large, finger-shaped (Figs. 3, 4).

9 (10) Apical part of the male subgenital plate, in profile, comparatively long and narrow, the upper projection narrow, finger-shaped. Head relatively narrow in the basal part (Fig. 3). Male wing slightly yellowish. Morocco. ..... **maroccana Dirsh**

10 (9) Apical part of the male subgenital plate in profile, comparatively short and broad, the upper projection short and broad, almost the same form as the apex of the plate. Head relatively broad in the basal part (Fig. 4). Male wing yellow. Tropical Africa. .... **confusa sp. n.**

11 (2) Head comparatively less elongated, robust, with broad basal part (Figs. 7, 17).

12 (13) Of medium size : ♂ up to 37.5, ♀ up to 63.0 mm. Elytron very narrow. The projection on the upper margin of the male subgenital plate, in profile, small (Fig. 7). Ethiopia. .... **herbacea I. Bol.**

13 (12) Of large size : ♂ up to 42, ♀ up to 83 mm. Elytron broad. The projection on the upper margin of the male subgenital plate, in profile, very large (Fig. 17). India. ..... **indica sp. n.**

14 (1) Transverse sulcus of pronotum about, or before the middle of pronotal disc (Figs. 5, 6, 8-16, 18-20, 22).

15 (42) Transverse sulcus about the middle of pronotal disc (Figs 5, 6, 8-12, 14-16, 18-20, 22).

16 (19) Male subgenital plate, in profile, short and broad, with shortened apical part ; the upper margin with a very large, broad projection. Apex of elytron is pointed. Wing comparatively broad (Figs, 5, 6).

17 (18) Male subgenital plate in profile with a very large projection on the upper margin, almost the same size as the rest of the plate (Fig. 5). Male wing in sexually mature specimens brownish-yellow, mat; in female, milky-mat. S. and tropical Africa. .... **sulphuripennis** (Gerst.)

18 (17) Male subgenital plate in profile, with the projection on the upper margin much smaller than the apical part of the plate (Fig. 6). Male wing in sexually mature specimens slightly yellowish-green and slightly mat; in the female pale yellowish-green, pellucid. S. Africa. ..... **propinqua** Burr

19 (16) Male subgenital plate, in profile, comparatively long with more elongated apical part, the upper margin with a small projection. Elytron with acute, subacute or parabolic, but not pointed apex. **Wing of normal shape** (Figs. 8-12, 14-16, 18-20, 22).

20 (21) Lateral carinae of pronotum straight or slightly incurved in prozona (Figs. 8-11, 14-16, 18-20, 22).

21 (30) Head comparatively robust, with [illegible] (Figs. 8, 9, 15, 16, 19).

22 (27) Male subgenital plate, in profile, short (Figs. 8, 9, 16). Internal upper lobe of the hind knee markedly longer than external one.

23 (26) Pronotum robust; [illegible] (Figs. 8, 9). **Head very robust.**

24 (25) Male subgenital plate, in profile, with acute apex. Lateral carinae of pronotum slightly incurved in prozona (Fig. 9). Size smaller. E. Africa. ..... **crassicollis** Chop.

25 (24) Male subgenital plate, in profile with obtuse apex. Lateral carinae of pronotum straight (Fig. 8). Size larger. S. Africa. .... **testacea** (Thunb.)

26 (23) Pronotum comparatively slender; [illegible]. **Head less robust (Fig. 16).** S. Asia. ..... **exaltata** (Walk.)

27 (22) Male subgenital plate, in profile, comparatively long (Figs. 15, 19). Internal upper lobe of the hind knee insignificantly longer than external one.

28 (29) Elytron with broadly parabolic apex. Lateral carinae of pronotum almost straight and almost parallel in their whole length, sometimes slightly incurved; in metazona not, or only slightly excurved (Fig. 15). S.W. Asia. ..... **oxycephala** (Pall.)

29 (28) Elytron with subacute apex. Lateral carinae of pronotum in prozona straight and slightly convergent towards head, in metazona slightly excurved (Fig. 19). Large and robust. S.E. Asia. .... **cinerea** (Thunb.)

30 (21) Head moderately robust, moderately broad in the basal part or slender and narrow in the basal part (Figs. 10, 11, 14, 18, 20, 22).

31 (36) Head moderately robust and moderately broad in the basal part. Elytron with subacute apex (Figs. 10, 11, 14).

32 (35) Male elytron is not curved backwards in the apical part (Figs. 10, 14).

33 (34) Comparatively robust. Lateral carina of pronotum in prozona incurved (Fig. 14). Caucasus. ..... **caucasica Dirsh**

34 (33) More slender. Lateral carina of pronotum, in prozona, straight or weakly incurved (Fig. 10). Africa, Mediterranean. .... **bicolor (Thunb.)**

35 (32) Male elytron curved backwards in the apical part (Fig. 11). S.E. Europe. ..... **ungarica (Herbst.)**

36 (31) Head comparatively slender and narrow in the basal part (Figs. 18, 20, 22).

37 (38) Fastigium of vertex very long ; in profile, the distance from the eye to the apex is slightly shorter than largest diameter of the eye (Fig. 18). Indo-China. ..... **lineata (Thunb.)**

38 (37) Fastigium of vertex shorter, in profile, the distance from the eye to the apex about two thirds of the length of the largest diameter of the eye (Figs. 20, 22).

39 (40) Male subgenital plate, in profile, with a large projection on the upper margin (Fig. 20). S. Asia, Malaya. ..... **willemsei sp. n.**

40 (39) Male subgenital plate, in profile, with a small projection on the upper margin (Fig. 22). Australia. ..... **conica (F.)**

41 (20) Lateral carina of pronotum undulated in prozona (Fig. 12). Madagascar. ..... **madecassa (Bransc.)**

42 (15) Transverse sulcus of pronotum distinctly before the middle of pronotal disc ; lateral carina in metazona very strongly excurved ; posterior angle of metazona strongly elongated, acutangulate and pointed (Fig. 13). Madagascar. ..... **subtilis Burr**

MEASUREMENTS OF ACRIDA SPECIES

SPECIES	BODY	ELYTRNO	HIND FEMUR	PRONOTUM	FRONS
A. acuminata, ♂	36.8-43.7	30.4-37.2	22.0-25.5	6.3-7.0	9.0-11.3
A. acuminata, ♀	60.5-71.6	55.0-71.0	34.4-42.0	11.2-11.8	15.0-17.4
A. turrita, ♂	40.4-57.8	33.4-50.5	24.4-35.3	6.2-8.8	9.9-15.4
A. turrita, ♀	57.8-106.2	51.7-92.0	32.0-56.1	10.5-15.8	14.3-24.4
A. maroccana, ♂	38.5-41.0	33.0-34.0	22.5-23.0	6.0-6.5	9.5-10.5
A. maroccana, ♀	65.0	60.0	35.5	11.5	14.5
A. confusa, ♂	35.0-40.5	31.0-36.1	22.2-25.0	5.9-6.7	9.8-11.0
A. confusa, ♀	59.0-65.5	53.1-56.2	33.0-37.2	9.3-10.8	13.9-15.1
A. sulphuripennis, ♂	31.0-38.7	25.0-31.0	19.5-23.2	5.4-6.0	7.7-9.3
A. sulphuripennis, ♀	53.0-63.2	44.0-56.2	29.5-36.8	8.4-11.0	12.1-14.4
A. propinqua, ♂	30.0-35.0	25.0-29.0	20.0-22.0	4.5-5.0	7.5-9.0
A. propinqua, ♀	48.0-56.0	43.0-47.0	31.5-33.0	8.0-9.0	12.0-13.5
A. herbacea, ♂	32.0-37.5	25.0-29.5	19.5-24.5	5.0-5.5	8.0-10.0
A. herbacea, ♀	53.0-63.0	43.0-51.0	33.5-37.0	9.0-11.0	12.0-13.0
A. testacea, ♂	32.0-39.0	26.0-31.0	22.0-25.0	5.5-6.0	8.0-9.5
A. testacea, ♀	49.0-58.0	40.0-49.5	33.0-39.5	9.5-10.0	12.5-13.5
A. crassicollis, ♂	25.7-32.0	22.6-27.7	16.0-21.0	4.8-6.1	6.0-8.2
A. crassicollis, ♀	40.2-58.5	36.0-41.5	25.3-28.8	8.6-9.3	10.2-10.8
A. bicolor, ♂	31.0-53.0	25.0-43.0	19.0-31.0	5.0-7.7	7.8-12.4
A. bicolor, ♀	51.0-80.0	42.7-63.2	31.0-46.0	8.5-13.0	11.5-17.5
A. ungarica, ♂	34.0-35.0	26.0-26.4	19.6-21.0	5.3-5.7	8.0-8.1
A. ungarica, ♀	50.0-54.5	40.0-41.0	30.0-31.0	9.0-9.2	12.5-12.7
A. madecassa, ♂	38.0-43.0	32.0-36.0	24.0-27.0	6.0-7.0	9.0-11.0
A. madecassa, ♀	60.0-74.0	49.0-63.0	34.5-41.0	9.5-12.0	14.5-18.0
A. subtilis, ♂	30.0-36.0	25.5-28.5	19.0-20.0	5.0-6.0	8.0-8.5
A. subtilis, ♀	50.0-54.0	39.5-41.0	28.0-30.5	10.0-10.5	12.5-13.0
A. caucasica, ♂	32.0-38.0	28.0-30.0	20.5-25.0	5.0-6.0	8.0-9.5
A caucasica, ♀	54.0-62.0	44.0-47.5	33.0-35.0	9.0-9.5	13.0-13.5
A. oxycephala, ♂	32.0-47.0	27.0-35.0	20.5-29.5	5.5-7.5	8.0-11.0
A. oxycephala, ♀	57.0-73.0	46.0-56.0	33.0-43.0	9.0-12.0	12.5-15.5
A. exaltata, ♂	28.5-37.0	23.5-34.0	18.5-22.0	5.0-6.0	7.0-9.0
A. exaltata, ♀	47.0-59.0	38.0-48.0	28.0-33.0	8.5-10.5	11.0-13.0
A. indica, ♂	42.0	34.0	27.0	7.0	9.5
A. indica, ♀	72.0-83.0	61.0-69.0	47.0-49.0	14.0-15.0	16.0-17.0
A. lineata, ♀	75.0	69.0	43.0	13.5	18.0
A. cinerea, ♂	38.0-47.0	30.0-39.0	24.0-26.0	6.0-8.0	9.0-10.5
A. cinerea, ♀	68.0-80.0	54.5-63.0	41.0-47.0	13.0-14.5	15.0-18.0
A. willemsei ♂	36.0-40.0	28.5-33.0	21.5-23.5	5.5-6.5	9.0-10.5
A. willemsei, ♀	54.0-70.0	63.0-76.0	30.5-45.0	9.0-12.5	12.5-17.5
A. cheesmanae, ♂	38.0-49.0	30.0-39.0	26.0-30.5	6.0-7.5	9.0-13.0
A. cheesmanae, ♀	69.0-72.0	59.0-61.0	43.5-45.0	11.0-11.5	16.0-17.5
A. conica, ♂	34.0-45.0	27.0-39.0	22.0-29.5	5.0-7.0	8.0-11.0
A. conica, ♀	50.0-70.0	40.0-58.0	30.0-41.0	8.0-11.0	11.0-16.5
A. carinulata ♀	70.0	68.0	41.0	11.0	—

LIST AND DESCRIPTION OF THE SPECIES

1. Acrida acuminata St.

1873, *Acrida acuminata* Stäl., Rec. Orth. : 97. — 1931, *Acrida acuminata* var. *histrionica* Sjöstedt, *Ark. f. Zool.*, XXIIA, 15:2.

Stäl described both sexes of this species but only the male remains, and is preserved in the Stockholm Museum. It was examined and fixed as the type. Type locality : « Caffraria », South Africa.

Type of Sjöstedt's *A. acuminata* var. *histrionica*, female, is also preserved in the Stockholm Museum. Type locality : «Kongo, Boko-Kinkala». It was examined and found to be a colour variation.

♂ (Type). — Redescription : Body strongly elongated and slender. Head strongly elongated ; from above and in profile, moderately widened ; in the basal part frons, in profile, little incurved. Antenna significantly shorter than head and pronotum together. Fastigium of vertex long, with parallel lateral sides and rounded apex.

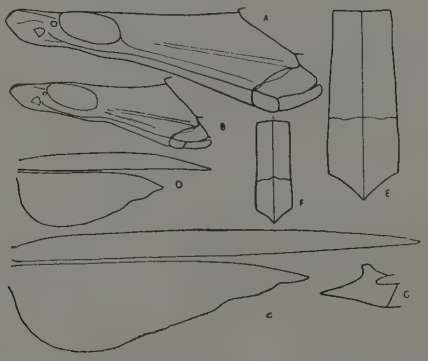


Fig. 1 : *Acrida acuminata :* (A) head of female ; (B) head of male ; (C) elytron and wing of female ; (D) elytron and wing of male ; (E) pronotum of female ; (F) pronotum of male ; (G) subgenital plate of male.

Lateral carinae of pronotum almost straight, parallel ; transverse sulcus far behind the middle of the disc of pronotum ; prosterior margin of metazona with a short acute angle, and incurved sides.

Elytron strongly produced beyond the hind knee, strongly narrow, with strongly elongated and pointed apex. Wing very narrow, shorter than elytron.

Lateral lobes of the hind knee short, acute, the upper lobe broader than the lower one.

Subgenital plate long, with strongly elongated acute apex and, in profile, with a large projection on the upper margin.

General colouration green ; apical part of elytra brownish ; wing lemon-yellowish, semipellucid ; slightly infumate on the apex.

♀. — Differs from the male by the following characters : much larger and even more slender ; elytron more elongated and pointed ; wing relatively narrower and more acute, with lighter colouration.

The chief characters of this species are : narrow disc of pronotum, with parallel carinae and transversal sulcus disposed beyond the middle ; elytron very narrow and pointed ; wing narrow and strongly narrowing to the apex, not transparent, pale-lemon coloured in both sexes. *A. acuminata* is not closely related to any known species.

It varies like any other species of the genus. Lateral carina of pronotum is sometimes lightly incurved (particularly in smaller specimens). Acuteness of the elytra is sometimes less than in the typical specimens. Colouration varies from uniformly green to brownish, sometimes with ochraceous longitudinal stripes from the eyes, throughout the upper margin of the lateral lobe of the pronotum and along the dorsal part of the elytra (var. *histrionica* Sjöst. has this type of colouration).

The South African specimens are most typical. Specimens from Tanganyika are smaller, with shorter and less acute elytra and wings, and may represent a local race. 24 ♂♂ and 35 ♀♀ were examined.

Geographical distribution : South Africa, S. Rhodesia, N. Rhodesia, Belgian Congo, Tanganyika Territory, Kenya (Map 5).

2. Acrida turrita L.

1758, *Gryllus* (*Acrida*) *turritus* Linné, Syst. Nat.: 10th ed.: 427, no. 12. — 1775, *Truxalis turritus* Fabricius, Syst. Ent.: 279. — 1805, *Truxalis refuscens* ♀, Palisot de Beauvois, Ins. Afr. Amer.: 17, f. 2. — 1805, *Truxalis tenuis* ♂, Palisot de Beauvois, Ins. Afr. Amer. : 17, f. 3. — 1825, *Truxalis nasutus* (partim)- Charpentier, Horae Ent.: 126. — 1907, *Acrida maxima* Karny, Sitz. Akad. Wien, CXVI : 107, f. 54, 55. — 1935, *Acrida turrita uvarovi* I. Bolivar, *Eos,* XI. 4 : 403. — 1949, *Acrida lineata* Dirsh (nec Thunberg), *Eos,* XXV : 22. — 1949. *Acrida turrita turrita* Dirsh, *Eos,* XXV : 24. — 1949, *Acrida turrita tunetana* Dirsh, *Eos,* XXV : 25. — 1949, *Acrida turrita sicula* Dirsh, *Eos,* XXV : 27. — 1949, *Acrida uvarovi* Dirsh, *Eos,* XXV : 29.

The type of *A. turrita* Linné described from « Africa » does not exist and the most common Algerian species has been arbitrarily chosen to represent *A. turrita* because this part of Africa was more accessible than other parts in Linné's time except Egypt, which he usually quoted as such (Dirsh, 1949).

The type of *Truxalis rufescens* (female) Palisot de Beauvois (type localities : « Chama, Oware et Benin ») was not seen, but on the basis of description and good figure and after studying a large amount of material from West Africa, it appears to be a synonym of *A. turrita,* together with *Truxalis tenuis* (male) of the same author and from the same localities.

Under the name of *Acrida maxima* Karny, one male and one female are preserved in the Vienna Museum, both from the same locality (Khor Attar, Goz Abu Guma, Anglo-Egyptian Sudan). The male was fixed as the type. They differ only by larger size, which probably depends on ecological conditions since specimens of this size occur in other localities.

A. turrita uvarovi I. Bolivar from Ifni, has been studied on topotypical material and may have a subspecific status but not a specific one.

Acrida lineata Dirsh (nec Thunberg) of which a large series was studied appears identical with *A. turrita* L. and may be regarded only as one of its local races. The type of T u n b e r g ' s *Tr lineatus* erroneously stated to be from Morocco was examined and was found to be an Eastern-Asiatic species (see page 152).

A. turrita tunetana Dirsh and *A. turrita sicula* Dirsh may remain as subspecies, but their relative status can only be established after studying the whole species statistically.

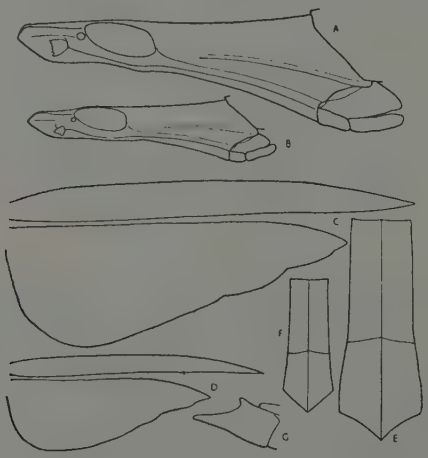


Fig. 2 : *Acrida turrita* (letter explanation as in Fig. 1).

It is impossible to decide without examination of specimens, what the previous authors understood under the names of *Acrida* or *Truxalis turrita* L. and *nasuta* L., and all old records must be disregarded.

♂ (of large size). — Body strongly elongated and slender.

Head strongly elongated, from above and in profile, narrow in the basal part ; frons in profile feebly incurved. Antenna almost as long as head and pronotum together. Fastigium of vertex long, with parallel lateral margins and obtusangulate, almost rounded apex.

Lateral carinae of pronotum almost straight, slightly incurved ; transverse sulcus little behind the middle of the pronotal disc ; posterior margin of metazona obtusangulate.

Elytron produced well beyond the hind knee, narrow, strongly elongated and acute towards the apex, which is strongly pointed. Wing moderately narrow, narrowing to the apex and insignificantly shorter than elytron.

Lateral lobes of the hind knee moderately long, acute ; upper lobe broader than lower one.

Subgenital plate elongated, with long acutangulate apex, in profile, with strong subacute projection in the upper basal half.

Colouration of wing varies from colourless to weakly lemon-yellowish.

♀. — As the male, but much larger.

A. turrita L. varies strongly in body size. Apex of fastigium of vertex varies from obtusangulate to rounded but its relative measurements remain stable. Form of the whole head appears a stable character The pronotum is most variable ; lateral carinae vary from almost straight and parallel to incurved and slightly divergent on whole length, and little excurved in metazona (mostly in small specimens) ; posterior margin of metazona varies from obtusangulate with straight sides to acutangulate, with incurved sides and pointed apex (the last is not so often). There is no connection between this variability and geographical distribution, and it probably depends on ecological conditions. Relative length of elytron varies slightly, but the general shape remains unchanged. The subgenital plate varies in length and acuteness of apex.

The largest specimens with most straight and parallel lateral carinae of pronotum occur in the southern part of Anglo-Egyptian Sudan, in Northern Rhodesia and in the Lake Chad area, while the smallest and most variable ones are found in the southern coastal part of Nigeria. Specimens from the typical locality (Northern Africa) are of medium size. 243 ♂♂ and 228 ♀♀ were examined.

Geographical distribution : S. Rhodesia, N. Rhodesia, Angola, Belgian Congo, Tanganyika Territory, Uganda, Gabon, Chad Territory, Nigeria, Dahomey, Gold Coast, Ivory Coast, French Sudan, Liberia, Sierra Leone, Gambia, Morocco, Algeria, Tunisia, Tripolitania, Sicily (Map 2).

3. Acrida maroccana Dirsh

1949, *Acrida maroccana* Dirsh, *Eos,* XXV : 27, figs. 6, 25, 43, 53, and 85.

♂ (Type). — Redescription : Large and slender.

Head strongly elongated ; from above and in profile slender, narrow in the basal part ; frons, in profile, little incurved. Antenae almost as

long as head and pronotum together. Fastigium of vertex long, with parallel lateral margin and truncate apex.

Lateral carinae of pronotum, in prozona, slightly incurved, almost straight, slightly divergent backwards ; in metazona straight and divergent ; transverse sulcus behind the middle of pronotal disc ; posterior margin of metazona rectangulate, with acute apex.

Elytron moderately produced beyond the hind knee, with elongated and narrowed apical part and strongly pointed apex. Wing moderately broad with subacute apical part.

Lateral lobes of the hind knee short, subacute ; upper lobe broader than lower one.

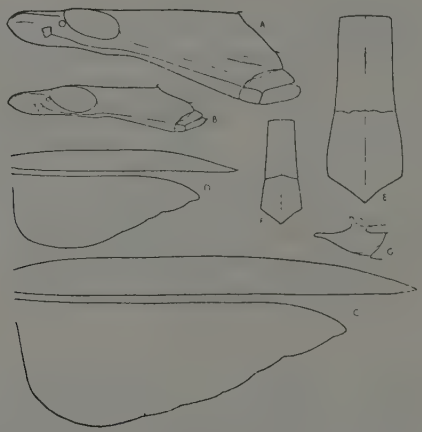


Fig. 3 : *Acrida maroccana* (letter explanation as in Fig. 1).

Subgenital plate strongly elongated, strongly narrowing in the apical part, with acute apex ; in profile with a large finger-shaped projection on the upper margin.

General colouration uniformly green ; wing light lemon-yellowish.

♀. — As the male, but much larger ; pronotal lateral carinae in metazona more excurved.

This species is similar to *A. turrita* by its head and elytra, but, on the other hand, its broader wing and the presence of a strong projection on the male's subgenital plate approximates it to *A. sulphuripennis*. 5 ♂♂, 1 ♀ were examined.

Geographical distribution : Morocco : Taroudant (Map 3).

4. Acrida confusa sp. n.

♂ (Type). — Of medium size and slender.

Head strongly elonged, from above and in profile, little broadened in the basal part. Frons, in profile, little incurved ; fastigium of vertex long, with parallel lateral margins and broadly obtusangulate apex.

Lateral carinae of pronotum, in profile, slightly incurved and slightly divergent forwards ; in metazona slightly divergent and scarcely excurved ; transverse sulcus a little behind the middle of the disc ; posterior margin of metazona obtusangulate with pointed apex and slightly incurved, almost straight, sides

Elytron well produced beyond the hind knee, narrow, strongly narrowing in the apical part, with pointed apex. Wing broad with narrow apical part ; slightly shorter than elytron.

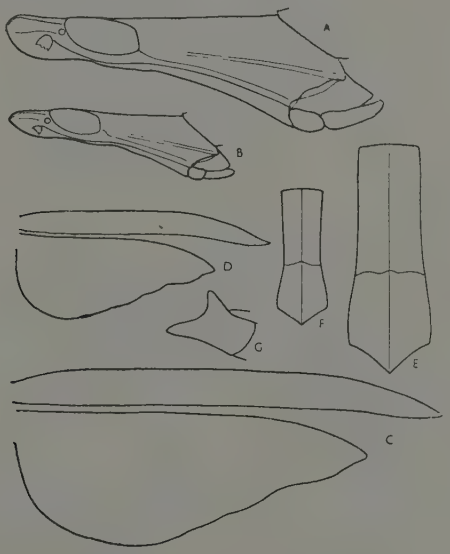


Fig. 4 : *Acrida confusa* (letter explanation as in Fig. 1).

Lateral lobes of the hind knee short, narrow and acute ; the lower lobe narrower and more acute than the upper one.

Subgenital plate moderately long, with moderately long acute apex ; in profile, the upper margin, near the middle with a large acute projection of almost the same size as the apex of subgenital plate.

General colouration green ; apical part of elytron light brownish, wing bright yellow, pellucid.

♀ (Paratype). — Differs from the male by much larger size ; head relatively broader in the base ; lateral carinae of pronotum slightly incurved and parallel or slightly convergent in prozona and more excurved in metazona ; the posterior angle of metazona with more acute apex. Colouration as in the male, but elytron often with characteristic pattern ; wing in mature specimens, light yellow, pellucid.

A. confusa is near to *A. sulphuripennis* but differs well by the more slender head ; more elongated pronotum with the transversal sulcus beyond the middle ; more longated subgenital plate, with the projection nearer to the middle of the upper margin, while in *A. sulphuripennis* it is nearer the apex ; by more acute apex of the wing and wing colouration, which is less deep yellow and pellucid. 120 ♂♂, 86 ♀♀ were examined.

A. confusa varies in the same ways as *A. sulphuripennis* and may be confused with the species, particularly in newly moulted specimens. Geographically the areas of these two species overlap and, therefore, they cannot be regarded as subspecies in spite of their similarity.

Geographical distribution : Type locality : Anglo-Egyptian Sudan, Gallard Forest, October-November 1950, 7 ♂♂, 1 ♀ (C.E. Wilson). Uganda, Kenya, Tanganyika Territory ; Nyasaland, N. Rhodesia, Belgian Congo, Angola, S.W. Africa, Cameroons, Togo, Gold Coast, Sierra Leone (Map 3).

5. Acrida sulphuripennis (Gerst.)

1869, *Tryxalis sulphuripennis* Gerstaecker, *Arch. f. Nat.*, XXXV : 215, f. 1.

Type locality : « Zanzibar ». The type was not examined, but the original description and very good figure makes its recognition possible.

♂. — Small and slender.

Head moderately elongated, from above and in profile, moderately broadened in the basal part ; frons, in profile, moderately incurved. Fastigium of vertex long, with parallel lateral margins and broadly obtusangulate apex.

Lateral carinae of pronotum, in prozona, weekly incurved and little divergent backwards ; in metazona slightly divergent and weakly excurved ; transverse sulcus in the middle of the disc ; posterior margin of metazona obtusangulate with almost straight sides.

Elytron little produced beyond the hind knee, relatively narrow, with strongly narrowed but short apical part, apex pointed. Wing broad, with short obtuse apical part, slightly shorter than elytron.

Lateral lobes of the hind knee short and acute ; the lower lobe narrower and more acute than the upper one.

Subgenital plate short with short, acute apex ; in profile, its upper margin near the apex with a large acute projection, apex of which is almost equal in size to the apex of the plate.

General colouration green ; apical part of the elytron lightish brown ; wing deep yellow mat. It newly moulted specimens wing mat, with slight yellowish tinge becoming brighter yellow during maturation and finally deep yellow, but still remaining mat and unpellucid.

♀. — Differs from the male by much larger size ; relatively broader basal part of the head ; more incurved (in most cases) lateral pronotal carina, less pointed elytron and less broadened with less broadened apex of wing. Colouration of wing in newly moulted specimens slightly yellowish, almost pellucid, during maturation becoming mat and in fully mature specimens milky-mat with weak yellowish-lemon tinge.

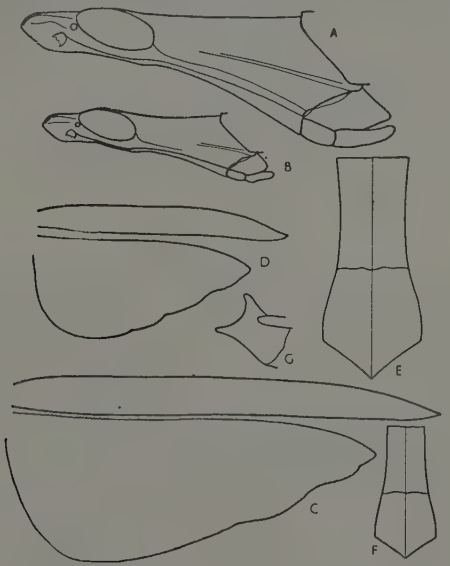


Fig. 5 : *Acrida sulphuripennis* (letter explanation as in Fig. 1).

Size of body varies greatly especially in the females. Lateral carinae of pronotum which vary in both sexes from gradually incurved in the whole length to almost straight in prozona and slightly excurved in metazona. Elytra and wing may have more or less acute apex. Male subgenital plate is a stable character.

General colouration varies from uniformly green to yellowish and brownish ; in the females the pattern is sometimes present on elytron, but in the males it is very rare. 241 ♂ ♂, 254 ♀ ♀ were examined.

Geographical distribution: S. Africa, Mozambique, S. Rhodesia, Nyasaland, Belgian Congo, Tanganyika Territory, Zanzibar, Kenya, Uganda, Ethiopia, Anglo-Egyptian Sudan, Togo, Gold Coast, Senegal (Map 4). Previous geographical records under the name *A. sulphuripennis* are not reliable and may refer to the next species and possibly also to *A. acuminata* and *A. confusa*.

6. Acrida propinqua Burr.

1902, *Acrida propinqua* Burr, *Trans. Ent. Soc. Lond.* 2 : 171, no. 16.

Burr described this species, male and female from « Cape Colony (Coll. Brunner, No. 16.698)» and male from «Slave Coast, Ho (Coll. Brunner, No. 17.437). I received from the Vienna Museum one male No. 16.698 and one female (without a number) and the male No. 17.437 ; the latter appears to be *Acrida bicolor* Thunb. The female has lost its number label but has a locality

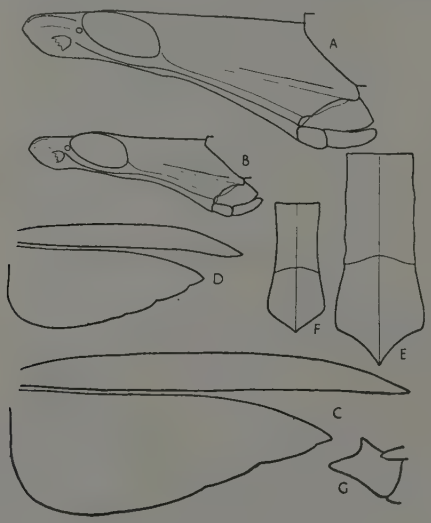


Fig. 6 : *Acrida propinqua* (letter explanation as in Fig. 1).

label identical with that mentioned by Burr, and corresponds perfectly with the measurements in Burr's description being undoubtedly the same specimen. I have designed the male specimen No. 16.698 as a specific type of *Acrida propinqua* Burr.

♂ (Type). — Redescription: Small and very slender.

Head moderately elongated ; from above and in profile, moderately widened in the basal part ; frons, in profile, incurved ; antenna shorter

than head and pronotum together. Fastigium of vertex long and relatively broad, with parallel sides and rounded apex.

Lateral carinae of pronotum, slightly incurved along the whole length ; transverse sulcus about the middle of pronotal disc ; posterior margin of metazona acutangulate and pointed.

Elytron little produced beyond the hind knee, narrow, with short, but acute apex. Wing moderately narrow, little shorter than elytron.

Lateral lobes of the hind knee short and acute, the internal upper lobe slightly longer than external one ; the lower lobes narrower and more acute than the upper ones.

Subgenital plate short, with short acute apex and, in profile, with large acute projection on the upper margin.

General colouration buff, with brownish stripe from eye along head. and lateral lobe of pronotum. Wing lemon-yellow, slightly mat.

♀. — Differs from the male by the following characters : much larger ; frons, in profile, less incurved ; lateral carina of pronotum in prozona parallel and slightly undulated in metazona weakly excurved ; wing relatively narrower. General colouration varies from uniformly green to brown ; wing colouration paler than in the males. 47 ♂ ♂, 30 ♀ ♀ examined.

7. Acrida herbacea I. Bol.

1922, *Acrida herbacea* ♀, I. Bolivar, Voyage Rothschild Ethiopie et Afr. Orient. Anglaise : 183. — 1922, *Acrida reducta* ♀, I. Bolivar, Voyage Rothschild Ethiopie et Afr. Orient. Anglaise : 185.

The type of *A. herbacea* I. Bol., female, is preserved in the Paris Museum and was examined. Type locality : « Ethiopie, Hieka : Bourka ».

The *A. reducta* I. Bol. type is also preserved in the Paris Museum and was examined. Type locality : « Ethiopie : Harar ». After studying a series of specimens of this species I believe that it is no more than a local or ecological race of *A. herbacea.*

♀ (Type). — Redescription : Of medium size and moderately robust.

Head moderately elongated, robust, from above and in profile, strongly widened in the basal part ; frons, in profile, moderately incurved. Antenna shorter than head and pronotum together. Fastigium of vertex long, broad, with parallel lateral sides and broadly rounded, almost truncate apex.

Lateral carinae of pronotum, in prozona almost parallel, only slightly convergent forwards and weakly undulated ; in metazona weakly excurved ; transverse sulcus beyond the middle of the disc ; posterior margin of metazona acutangulate and pointed.

Elytron produced little beyond the hind knee, narrow in the apical third, strongly narrowing to the apex, which is moderately acute. Wing considerably shorter than elytron, strongly narrowed, with acute apex.

Lateral lobes of the hind knee short and acute, upper lobe almost equal in width to the lower one.

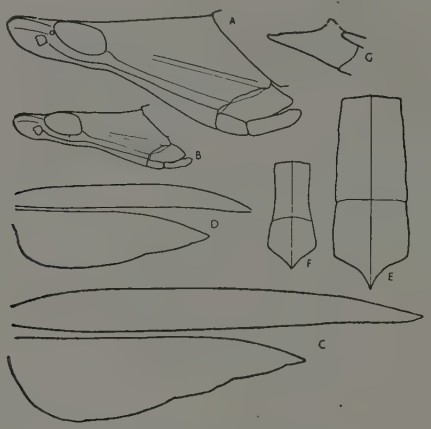


Fig. 7 : *Acrida herbacea* (letter explanation as in Fig. 1).

General colouration uniformly green ; wing pellucid. slightly grlenish-yellow.

♂. — Differs from the female by the following characters : much smaller ; lateral carina of pronotum, in prozona, varies from straight to incurved, in metazona more distinctly excurved ; wing relatively longer ; subgenital plate long, with long acute apex and, in profile, with an obtuse projection on the upper margin.

A. herbacea varies strongly in body size, form of lateral carinae of pronotum, which are mostly parallel and almost straight on the whole length, but sometimes slightly undulated or incurved in prozona and slightly excurved and divergent in metazona. Length and width of wing varies, but the wing remains generally narrow and acute. Width of head in the basal part also varies. 8 ♂♂, 12 ♀♀ were examined.

Geographical distribution : Ethiopia (Map 5).

8. Acrida testacea (Thunb.)

1815, *Truxalis testaceus* Thunberg, *Mem. Acad. Petersb.*, V : 265. — 1827, *Truxalis testaceus* Thunberg, *Nova Acta Ups.*, IX : 81.

Under the name *Tr. testaceus* in Thunberg's collection in Uppsala Museum there are two females, one of which I have fixed as the specific type.

The second is a female of *A. bicolor* Thunb.

Thunberg did not record the locality of this species, but having compared it with all studied ones, I regard it as, most probably, South African.

♀ (Type). — Redescription : Body of medium size and moderately slender.

Head comparatively short and robust ; strongly widened in the basal part ; frons, in profile, moderately incurved. Fastigium of vertex almost as long as broad, with broadly rounded apex.

Lateral carinae of pronotum, in prozona straight, scarcely convergent forwards ; in metazona excurved ; transversal sulcus about the middle of the disc ; posterior margin of metazona strongly acute with incurved sides.

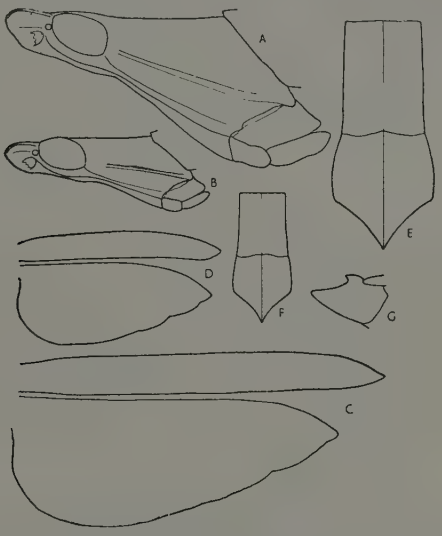


Fig. 8 : *Acrida testacea* (letter explanation as in Fig. 1).

Elytron little projecting beyond the apex of the abdomen, relatively broad, with short, broad, almost obtusangulate apex. Wing moderately broad, with acute apex.

Upper lateral lobes of the hind knee long and acute, the internal lobe markedly longer than the external one ; the lower lobes short and acute.

Type specimen is discoloured ; other specimens vary from green to brownish ; the pattern of elytron sometimes present ; wing light yellowish, pellucid.

♂. — Much smaller than the female and relatively more robust.

Head relatively short and robust, strongly widened in the basal part ;

frons, in profile, moderately incurved. Fastigium of vertex almost as long as broad, with broadly rounded apex.

Lateral carinae of pronotum, in prozona, almost straight, scarcely convergent forwards, in metazona weakly excurved ; transverse sulcus about the middle of pronotal disc ; posterior margin of metazona strongly acute and pointed, with incurved sides.

Elytron scarcely projecting beyond the hind knee, broad, with short, broad, almost obtusangulate apex, which is lightly bent backwards. Wing broad, with moderately broad apex.

Lateral lobes of the hind knee shorter than in the female, upper internal lobe slightly longer than the external one.

Subgenital plate short, with broad subacute apex and. in profile, with a small acute projection on the base of upper margin.

General colouration varies from uniformly green to brownish ; wing light yellowish, pellucid.

A. testacea varies strongly in body size ; from pronotal disc, which may be more or less slender ; more or less obtuse wing (in females) and even in shape of head which may be more or less broad, but its robust character remains always.

This species belongs to the same group as *A. crassicollis* Chop.; they both have : the internal upper lobe of the hind knee slightly longer than external one, robust, short head and short elytron with obtuse apex. On the other hand, the form of elytron, of head and of subgenital plate is different (see Figs. 8 and 9) ; the wing in *A. crassicollis* is broader at the apex. 4 ♂♂, 5 ♀♀ were examined.

Geographical distribution : S. Africa (Map 5).

9. Acrida crassicollis Chop.

1921, *Acrida crassicollis* ♀, Chopard, Voyage Afr. Orient. Anglaise Babault : 44.

Type female, preserved in the Paris Museum was examined.

Type locality : « Kedong Valley (Afrique orientale Anglaise) ».

♀ (Type). — Redescription : Body of medium size and comparatively robust.

Head comparatively short and robust ; from above and in profile, strongly widened in the basal part ; frons in profile strongly incurved. Antenna shorter than head and pronotum together. Fastigium of vertex comparatively short and broad, narrowing to the apex, which is broadly rounded, almost truncate.

Lateral carinae of pronotum, in prozona, parallel, slightly undulated ; in metazona little excurved ; transverse sulcus in the middle of the disc ;

posterior margin of metazona strongly acute and pointed, sides of the angle incurved.

Elytron little produced beyond the hind knee, comparatively broad, with short parabolic apex. Wing broad, slightly shorter than elytron.

Upper lateral lobes of the knee long and acute, the internal lobe slightly longer than external one ; the lower lobes short and acute

Type specimen is discoloured (from alcohol).

♂ . — Much smaller than the female, short and comparatively robust.

Head short and robust, strongly widened in the basal part ; frons, in profile, strongly incurved. Antenna shorter than head and pronotum to-

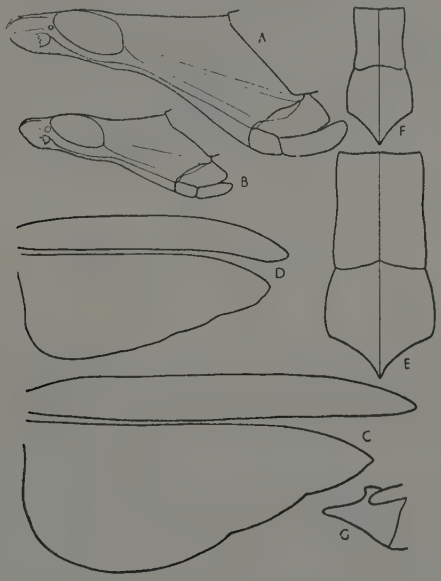


Fig. 9 : *Acrida crassicoilis* (letter explanation as in Fig. 1).

gether. Fastigium of vertex comparatively short, with parallel lateral sides or slightly narrowing to the apex, which is broadly obtusangulate.

Lateral carinae of pronotum, in prozona incurved and slightly undulated; in metazona excurved ; the transverse sulcus before the middle of the pronotal disc ; posterior margin of metazona strongly acute and pointed and with incurved sides.

Elytron projecting little beyond the hind knee, broad, with short, bent backwards, parabolic apex. Wing broad, with broad apex, almost as long as elytron.

Upper lateral lobes of the hind knee long and acute, the internal lobe

markedly longer than the external one ; the lower lobes short and acute.

Subgenital plate short and broad, with acute apex and, in profile, with the strong projection ou the upper margin about the middle.

General colouration varies from uniformly green to ochraceous and brownish ; the pattern of elytra sometimes present ; wing weak lemon-yellowish ; slightly infumate.

Six specimens from Ethiopia and twenty five from Somaliland were studied and compared with type. Ethiopian specimens appear to be the most typical, the Somalian ones are more slender.

The fastigium of vertex varies from parallel-sided to slightly convergent to the apex which varies from truncate to obtusangulate or broadly rounded. Lateral carinae of pronotum vary from almost straight in prozona to slightly undulated or incurved ; the pronotal disc varies from broad as in typical specimens to comparatively narrow. The best characters which are always stable are the broad, robust head, form of elytron and internal upper lobe of the hind knee which is always slightly longer than external one.

Geographical distribution : Kenya, Ethiopia, British Somaliland, Eritrea (Map 5).

10. Acrida bicolor (Thunb.)

1815, *Truxalis bicolor* Thunberg, *Mem. Acad. Petersb.*, V : 266, f. 3. — 1827, *Truxalis bicolor* Thunberg, *Nova Acta Ups.*, IX : 87. — 1830, *Truxalis pellucida* Klug, Symb. Phys., no. 9, pl. 18, f. 7. — 1893, *Tryxalis stali* I. Bolivar, *Feuille Jeunes Nat.*, XXVII : 162, 164, no. 8. — 1919, *Acrida orientalis* I. Bolivar, *Bull. Soc. entom. France :* 242. — 1922, *Acrida orientalis* I. Bolivar, Voyage Rothschild Ethiopie et Afr. Orient. Anglaise : 184, f. 4. — 1922, *Acrida deminuta* I. Bolivar, Voyage Rothschild Ethiopie et Afr. Orient. Anglaise : 183. — 1931, *Acrida tesselata* Sjôstedt, *Arkiv. f. Zool.*, XXII A, 17:5, f. 2. — 1934, *Acrida leopoldi* Sjôstedt, *Bull. Hist. Nat. Belg.*, X, 4:1, f. 1. — 1949, *Acrida pellucida pellucida* Dirsh, *Eos,* XXV : 30, f. 9, 28, 46, 56, 88. — 1949, *Acrida pellucida algeriana* Dirsh, *Eos,* XXV : 32 f. 8, 27, 45, 55, 87 . — 1949, *Acrida pellucida palaestina* Dirsh, *Eos,* XXV : 33, f. 10, 29, 47, 57, 89. — 1949, *Acrida pellucida cypria* Dirsh, *Eos,* XXV : 34, f. 30, 48, 58, 90. — 1949, *Acrida anatolica* Dirsh, *Eos,* XXV : 34, f. 11, 31, 49, 59, 91. — 1949, *Acrida mediterranea mediterranea* Dirsh, *Eos,* XXV : 36, f. 13, 32, 60, 70, 72. — 1949, *Acrida mediterranea bosphoriva* Dirsh, *Eos,* XXV : 37, f. 12, 61, 71, 93. — 1949, *Acrida mediterranea lombardica* Dirsh, *Eos,* XXV : 38, f. 14, 33, 62, 72, 94. — 1951. *Acrida meridionalis* Ramme (nomen erratum), *Mitt. Zool. Mus. Berlin,* p. 383.

Under the name *Tr. bicolor* Thunb. in Thunberg's collection in Uppsala Museum there is one male specimen, which I have fixed as the type. This species was described without any record of its origin. It was compared with a vast amount of material and is most probably of South African origin. It was also compared with all specific types of the above mentioned synonyms (except *T. pellucida* Klug).

The type of *Acrida stali* I. Bol., a male, is preserved in the Madrid Museum ; type locality « Senegal ». It differs from *A. bicolor* by larger size and uniformly green general colouration, which is a common colour variation.

The type of *A. orientalis* I. Bol., a male, is preserved in the Paris Museum ; type locality : « Ethiopie Meridionalis ». It is of small size and similar to South African specimens.

Type of *A. deminuta* I. Bol., a male ; type locality : «Ethiopie, Karssa», preserved in the Paris Museum, differs only by its dark brown colouration ; it is also small like South African specimens.

Type of *A. tesselata* Sjœst, a male ; type locality : « Ob. Volta, Pundu »,

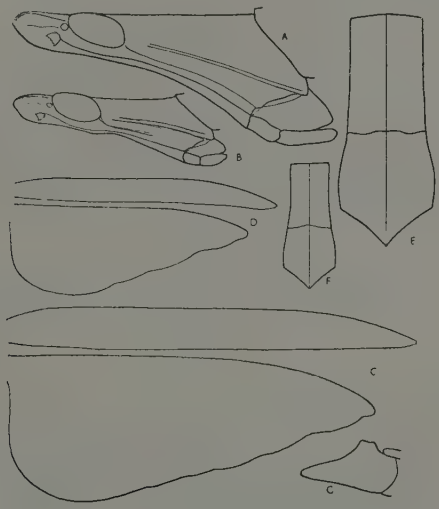


Fig. 10 : *Acrida bicolor* (letter explanation as in Fig. 1).

preserved in the Stockholm Museum. It is very similar to the type of *A. stali* I. Bol., differing only by the darker wing colouration which is usual in sexually mature specimens.

Type of *A. leopoldi* Sjôst., a male ; type locality : « Congo Belge, Plaine du Parc National Albert », preserved in the Brussels Museum. It has no differences from the type *A. tesselata* except smaller size and a deformity of the left wing (see Fig. 1 in Sjôstedt's description), a character which Sjôstedt regarded as specific, but the right wing is quite normal and does not differ from the wing of this species.

T. pellucida may be easily recognised from the good figure given in Klug's description. This is only synonym, the type of which was not examined.

♂ (Type). — Redescription : Of medium size. Body moderately elongated and slender.

Head moderately elongated, from above and in profile, moderately robust and broadened in the basal part ; frons, in profile, strongly incurved. Fas-

tigium of vertex moderately long, with parallel, slightly divergent to the base, lateral margins and broadly obtusangulate apex.

Lateral carinae of pronotum in prozona parallel, in metazona excurved ; transverse sulcus in the middle of the disc ; posterior margin of metazona acutangulate with weakly incurved sides.

Elytron little produced beyond the hind knee moderately narrow, with short apical part and subacute apex. Wing relatively broad, with obtuse apex, little shorter than elytron.

Lateral lobes of the hind knee moderately long and acute, upper lobe almost the same width as the lower one.

Subgenital plate elongated, with acutangulate apex ; in profile, with obtuse projection on the upper margin.

General colouration green, with broad ochraceous longitudinal stripes on the head, upper margin of lateral lobe of pronotum and dorsal half of elytra. Wing honey-yellow, slightly brownish.

♀. — As the male, but much larger, with head broader at the base, more excurved lateral carinae of pronotum in metazona and more acutangulate posterior margin of metazona. Colouration of wing lighter and less infumate.

The most variable characters of *A. bicolor* are : size of body and form of disc of pronotum ; lateral carinae in prozona vary from parallel to incurved, in metazona, from slightly to strongly excurved ; posterior angle of metazona also varies. Elytron varies in width, but the general shape remains stable. Form of head is a most stable character, but fastigium of vertex may be more or less narrowing towards apex. Subgenital plate varies in its length and size of projection, but the general type remains stable. Colour varies from uniformly green to yellow ochraceous and brownish with more or less strongly developed pattern of elytra. Wing in immature specimens slightly honey-yellowish, gradually this colouration becomes more intensive ; in the tropical zone, in mature male specimens, on the intense honey-yellow background, a brown suffusion appears, and sometimes spreads over the greater part of the wing. In the females the wing colouration is much less intense and even in a mature specimen the brown colour sometimes does not appear.

A. bicolor is one of the most widely distributed and variable species. Even now this species may be divided, with some degree of probability, into the following geographical subspecies.

(1) The typical subsp. *bicolor* Thunb. occurs in S. Africa. It differs by smaller size and more slender habitus, and gradually approaches the next subspecies.

(2) Subsp. *stali* I. Bol. is widely distributed in the whole of tropical

Africa. It differs by larger size, more robust body and very dark brownish wing in mature specimens.

(3) Subsp. *orientalis* I. Bol., smallest in size and most slender, very similar to the S. African subspecies, occurs in Ethiopia and Somaliland.

(4) Subsp. *pellucida* Klug found in North Africa and along the Mediterranean Sea to Syria, differs from the typical subspecies by the absence of brown colouration of wing in mature specimens.

(5) Subsp. *anatolica* Dirsh occurring in Asia Minor, differs from the previous subspecies by more robust body and pronotum ; in mature specimens, wing is not infumate.

(6) Subsp. *mediterranea* Dirsh found in the Mediterranean region of Europe, differs by small size, more slender body and also by wings, which are not darkened in mature specimens.

Taken separately, or in small series, each subspecies may be considered as a distinct species, but in a large series all intermediate forms may be found.

There are probably many other subspecies, but further ecological and biometrical investigations are necessary before they can be distinguished. 719 ♂♂ and 560 ♀♀ were examined.

Geographical distribution : S. Africa, Bechuanaland, Mozambique, S. Rhodesia, N. Rhodesia, Angola, Belgian Congo, Nyasaland, Tanganyika Territory, Uganda, Kenya, Somalia, British Somaliland, Ethiopia, Anglo-Egyptian Sudan, Chad Territory, Nigeria, Gold Coast, Senegal, Algeria, Tunisia, Egypt, Palestine, Syria (coastal zone), Asia Minor, Europ. Turkey, Greece, Yugoslavia, Italy, S. France, S. Spain, Sardinia, Corsica, Sicily, Cyprus (Map 6).

11. Acrida ungarica (Herbst.)

1786, *Truxalis ungaricus* Herbst, Fuessly Arch. Ins. : 192, pl. 52. — 1793, *Truxalis hungaricus* Fabricus, Ent. Syst. II : 27. — 1827, *Truxalis ungaricus* Thunberg, *Nova Acta Ups.*, IX : 88. — 1949, *Acrida ungarica* Dirsh, *Eos*, XXV : 39, f. 15, 34, 63, 95.

♂. — Of small size and slender.

Head strongly elongated and slender, its basal part moderately widened from above and in profile; frons, in profile, moderately incurved. Antenna shorter than head and pronotum together. Fastigium of vertex moderately elongated, with parallel lateral margins and broadly rounded apex.

Lateral carinae of pronotum in prozona weakly incurved, in metazona excurved or straight ; transverse sulcus about the middle of pronotal disc ; posterior margin of metazona obtusangulate.

Elytron little produced beyond the hind knee, relatively narrow, with little narrowed apical part, which is curved posteriorly ; apex subacute,

approximate to parabolic. Wing moderately broad with slightly obtuse apex.

Lateral lobes of the hind knee short and acute ; upper lobe broader than lower one.

Subgenital plate short, with narrowing apical part and subacute apex ; projection on the upper margin, seen in profile, broad and obtuse.

General colouration varies from uniformly green to brownish ; elytron sometimes uniformly coloured, sometimes with the pattern. Wing light yellowish, pellucid.

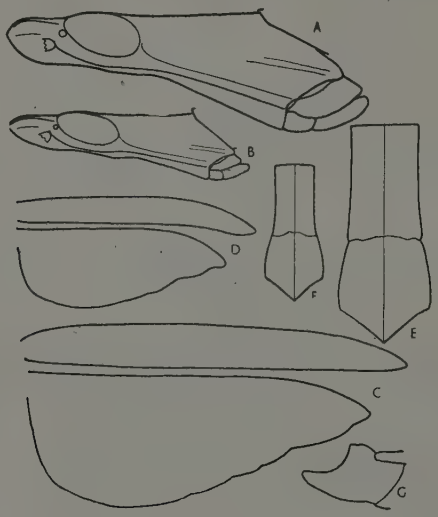


Fig. 11 : *Acrida ungarica* (letter explanation as in Fig. 1).

♀. — As the male, but larger ; apical part of elytron is not curved, or only slightly curved, posteriorly.

This species varies in body size, form of lateral pronotal carinae, degree of acuteness of wing and acuteness of subgenital plate.

A. ungarica is nearest to *A. bicolor,* but differs by distinctly curved posterior margin of male's elytra, by more slender habitus and shorter subgenital plate of male.

Geographical distribution : Hungary, Rumania (Map 6).

Records of « *A. turrita* » from European Russia should probably be referred to this species.

12. Acrida madecassa (Brancs.)

1893, *Tryxalis madecassa,* ♀, Brancsik, *Jahresh. Ver. Trencs.,* XXV—XXVI : 186.

♂. — Large and slender.

Head strongly elongated, slender, relatively narrow in the basal part ; frons, in profile, weekly incurved. Antenna shorter than head and pronotum together. Fastigium of vertex long, with parallel lateral margins and rounded apex.

Lateral carinae of pronotum, in prozona, undulated, in metazona excurved ; transverse sulcus slightly behind the middle of pronotal disc ; posterior margin of metazona weakly acute with incurved sides.

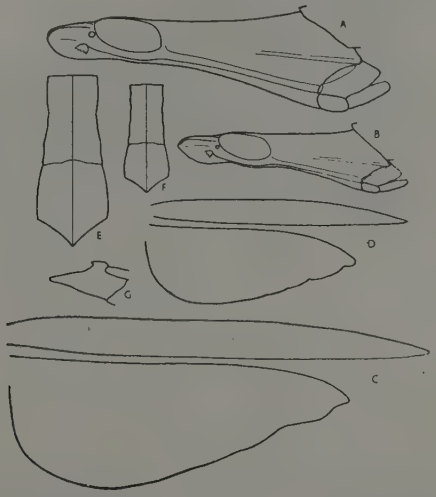


Fig. 12 : *Acrida madecassa* (letter explanation as in Fig. 1).

Elytron well produced beyond the hind knee, narrow, with elongated and acute apex. Wing moderately narrow, with moderately acute apex.

Lateral lobes of the hind knee short and acute ; upper lobe broader than lower one.

Subgenital plate long, with elongated, acute apex ; on the upper margin, in profile, a small subacute projection.

General colouration varies from green to brownish, elytron uniformly green or with pattern, mostly brownish on the apex ; wing slightly yellowish, sometimes weakly infumate.

♀. — As the male but much larger.

Lateral carina of pronotum, in prozona, more strongly undulated and pronotal sulcus in the middle of the disc.

The type of this species was not examined. Type locality : « Madagascae, Sinus Baliensis-Suabala ». 8 ♂♂, 27 ♀♀ were examined.

Geographical distribution : Madagascar (Map 4).

13. Acrida subtilis Burr.

1902, *Acrida subtilis* ♂, Burr., *Trans. Ent. Soc. Lond.*, II : 171, no. 15.

♂. — Of medium size and relatively robust.

Head moderately elongated, from above and in profile, strongly widened in the basal part ; frons, in profile, little incurved. Antenna shorter than

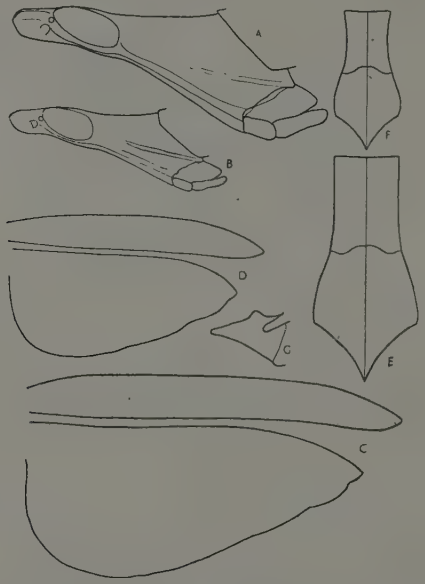


Fig. 13 : *Acrida subtilis* (letter explanation as in Fig. 1).

head and pronotum together. Fastigium of vertex long, narrow, with broadly rounded apex.

Lateral carinae of pronotum, in prozona strongly incurved, in metazona strongly excurved and divergent ; transverse sulcus before the middle of pronotal disc ; posterior margin of metazona strongly acutangulate and pointed, with incurved sides.

Elytron little produced beyond the hind knee, broad, with short, broad apical part and broadly parabolic apex. Wing broad, with broad apical part.

Lateral lobes of the hind knee moderately long, acute, upper lobe slightly broader than lower one.

Subgenital plate moderately long, with subacute apex and, in profile, with a small projection on the upper margin.

General colouration green ; elytra green, sometimes with more or less developed pattern ; wing slightly yellowish, sometimes weakly infumate.

♀. — As the male, but larger.

Head relatively more widened in the basal part ; colouration of wing slightly yellowish without any darkening.

The type of *A. subtilis* Burr is in Vienna Museum. Type locality : « Madagascar ». 5 ♂♂, 7 ♀♀ were examined.

Geographical distribution : Madagascar (Map 4).

14. Acrida caucasica Dirsh

1949, *Acrida caucasica* Dirsh, *Eos*, XXV : 40, f. 16, 35, 35, 64, 74, 96.

♂. — Of medium size and slender.

Head elongated, moderately robust and broadened in the basal part ; frons, in profile, moderately incurved. Antenna shorter than head and pro-

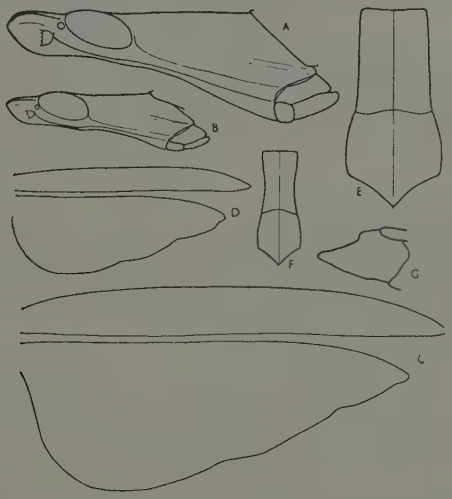


Fig. 14 : *Acrida caucasica* (letter explanation as in Fig. 1).

notum together. Fastigium of vertex elongated with parallel lateral margins and rounded apex.

Lateral carinae of pronotum, in prozona, strongly incurved, in metazona excurved and divergent ; transverse sulcus about the middle of pronotal disc ; posterior angle of metazona obtuse, with sharp apex and incurved sides.

Elytron moderately produced beyond the hind knee, with short apical part and subacute, approximate to parabolic, apex. Wing moderately broad, with narrow apical part.

Lateral lobes of the hind knee short and acute : upper lobe broader than lower one.

Subgenital plate short and broad, with obtuse apex ; in profile, on the upper margin, with a small broad projection.

General colouration varies from green to brownish ; elytron uniformly coloured or with pattern ; wing light greenish-yellow, pellucid.

♀. — As the male but larger, lateral carinae of pronotum, in prozona, straight or slightly incurved, in metazona more excurved than in the male.

Shape of pronotum in *A. caucasica,* in spite of the variability of this character, differs strongly from that in other species. This character and also form of elytron and shape of head make it quite distinctive. 11 ♂♂, 6 ♀♀ were examined.

Geographical distribution : Caucasus and Transcaucasia : Tiflis, Batum, Kutais, Geok-Tapa (Map 7). Type locality : Caucasus, Tiflis.

15. Acrida oxycephala (Pall.)

1801, *Gryllus oxycephalus* Pallas, Reise I : 468. — 1916, *Acrida turrita deserti* Uvarov, *Rev. Russe d'Ent.,* XVI : 10. — 1928, *Acrida deserti* Tarbinsky, *Bull. Inst. Zool. Appl. Zool. Phyt.,* IV : 54. — 1940, *Acrida oxycephala* Tarbinsky, Orth. Ins. Azerb. Moscow : 166. — 1949, *Acrida oxycephala* Dirsh, *Eos,* XXV : 41. — 1949, *Acrida deserti* Dirsh, *Eos,* XXV : 42. — 1949, *Acrida persa* Dirsh, *Eos,* XXV : 44. — 1949, *Acrida turca* Dirsh, *Eos,* XXV : 44. — 1949, *Acrida caspica* Dirsh, *Eos,* XXV : 45.

This species, first described by Pallas, is taken in broader limits, covering all species mentioned in synonymy, which are regarded as lower taxonomic units and need statistical treatment and bio-ecological study.

♂. — Of medium size and moderately slender.

Head moderately elongated, robust and strongly widened in the basal part ; frons, in profile, strongly incurved. Antenna shorter than head and pronotum together. Fastigium of vertex moderately elongated, with parallel lateral sides and broadly obtusangulate apex.

Lateral carinae of pronotum weakly incurved, almost straight on the whole length ; transverse sulcus almost in the middle of pronotal disc ; posterior margin of metazona acutangulate, with slightly incurved sides.

Elytron little produced beyond the apex of the abdomen, broad, with short and broad apical part and broadly parabolic apex. Wing broad, with moderately broad apical part, little shorter than elytron.

Lateral lobes of the hind knee short and acute.

Subgenital plate moderately long, broad, with subacute apex and, in profile, with an obtuse projection on the upper margin.

General colouration green ; wing light greenish-yellow, pellucid.

♀. — As the male, but much larger.

This species varies strongly in form of pronotal carinae from straight and parallel to more or less incurved and sometimes excurved in metazona. Fastigium of vertex varies in its width. Subgenital plate varies in its

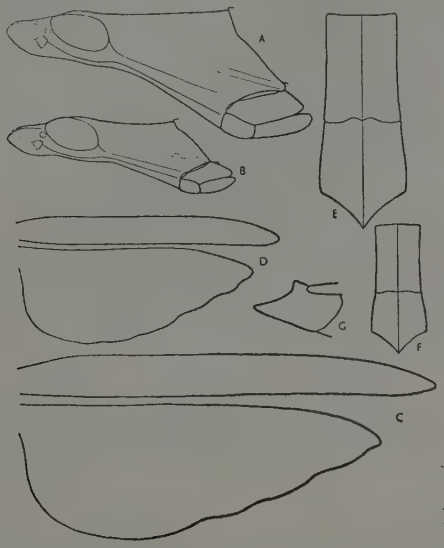


Fig. 15 : *Acrida oxycephala* (letter explanation as in Fig. 1).

length and more or less developed projection. Colouration varies from uniformly green to ochraceous and brownish ; elytra in fifty per cent of specimens with pattern.

Geographical distribution : Transcaucasia, Eastern Turkey, Persia (northern part), Afghanistan, Russian Central Asia (probably), northern coast of the Caspian Sea (Map 7). Type locality : Northern coast of Caspian Sea.

16. Acrida exaltata (Walk.)

1859, *Truxalis exaltata* Walker, *Ann. Nat. Hist.*, IV : 222. — 1893, *Tryxalis brevicollis* I. Bolivar, *Feuille Jeunes Nat.*, XXVII : 162, 164, no. 8. — 1902, *Acrida lugubris* Burr, *Trans. Ent. Soc. Lond.*, II : 170, n. 13. — 1936, *Acrida curta* Uvarov, *Linn. Journ. Zool.*, XXXIX : 536.

The type of *A. exaltata* Walk., a female, is preserved in the British Museum. The type locality : « Ceylon ».

Acrida brevicollis I. Bol. the type, a male, is preserved in the Madrid Museum ; type locality : « Madure, India orientalis ». The type was examined and compared with males of *A. exaltata* Walk. from Ceylon.

Under the name *Acrida lugubris* Burr, there are preserved in the Vienna Museum, two males and two females from Ceylon. All four do not differ from *A. exaltata* Walk. I have fixed male No. 5696 as specific type.

A. curta Uv., paratypes preserved in the British Museum, type locality : Arabia, Yemen, Sana'a. After studying a large series from the typical locality this species was found identical with *A. exaltata* Walk. and may only be a

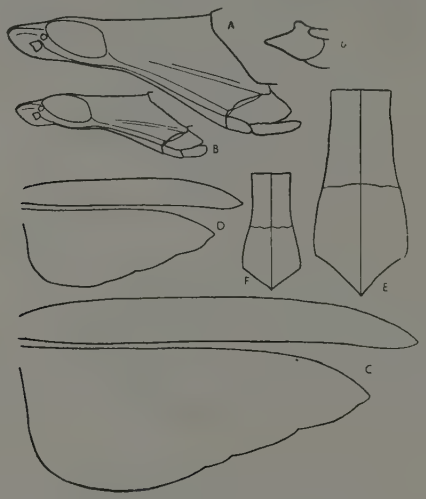


Fig. 16 : *Acrida exaltata* (letter explanation as in Fig. 1).

local race, which is connected through Persia and India by all intermediate forms with the typical *A. exaltata*.

♂ (Type). — Redescription : Of medium size and moderately slender.

Head moderately robust ; from above and in profile, strongly broadened in the basal part ; frons, in profile, strongly concave. Antenna shorter than head and pronotum together. Fastigium of vertex moderately long, with parallel lateral margins and broadly rounded apex.

Lateral carinae of pronotum, in prozona, slightly undulated and convergent forwards, in metazona slightly excurved and divergent ; transverse sulcus slightly before the middle ; posterior margin of metazona acutangulate, with weakly incurved sides.

Elytron little produced beyond the hind knee, relatively broad, with short and broad apical part and parabolic apex. Wing slightly shorter than elytron, broad with obtuse apex.

Lateral lobes of the hind knee moderately long and acute.

General colouration uniformly green. Wing weakly greenish-yellow, the greater part of the basal disc brownish, infumate.

♀. — Differs from the male by the following characters : body much larger, lateral carinae of pronotum, in prozona, mostly incurved, in metazona divergent, posterior margin of metazona less acute ; subgenital plate short and broad, in profile, with acute apex and a small obtuse projection on the upper margin. Wing usually more infumate and darker.

A. exaltata varies in general colouration from uniformly green to ochraceous and brownish ; the pattern of elytron sometimes present, but only in the females ; wing in newly moulted specimens pellucid and almost colourless, the brownish darkening developing gradually during maturation and is darkest in sexually mature specimens ; this darkening is more developed in males, in females sometimes absent even in the mature specimens. Most variable of the structural characters is the size of body and form of pronotal lateral carinae, which vary from almost straight, in prozona, to incurved and undulated.

This species is nearest to *A. willemsei,* from which it differs by the more robust body, more robust and relatively shorter head, shorter elytra and particularly by the shape of the male subgenital plate. 154 ♂♂, 161 ♀♀ were examined.

Geographical distribution : Ceylon, India, Pakistan, Assam, Kashmir, S.E. Tibet, Afghanistan, S.E. Persia, Arabia : Yemen, W. Aden Protectorate (Map 7).

17. Acrida indica sp. n.

♂ (Type). — Of moderate size and robust.

Head robust, strongly broadened in the basal part ; frons, in profile, weakly incurved. Antenna slightly shorter than head and pronotum together. Fastigium of vertex moderately long, slightly narrowing to the apex, which is obtusangulate.

Lateral carinae of pronotum straight and almost parallel, slightly convergent forwards ; transverse sulcus beyond the middle of pronotal disc ; posterior margin of metazona acutangulate and pointed.

Elytron slightly produced beyond the hind knee, broad, with short, little narrowed apical part and subacute apex. Wing shorter than elytron, broad, with obtuse apex.

Lateral lobes of the hind knee short and acute, the upper lobe broader than the lower one.

Subgenital plate broad, moderately long, with acute apex and, in profile, with large obtuse projection in the basal part.

General colouration green ; elytron slightly brownish in the apex ; wing pellucid, slightly yellowish.

♀ (Paratype). — Body much larger than in the male and much more robust.

Head much more robust and more strongly widened in the basal part ; frons, in profile, less incurved.

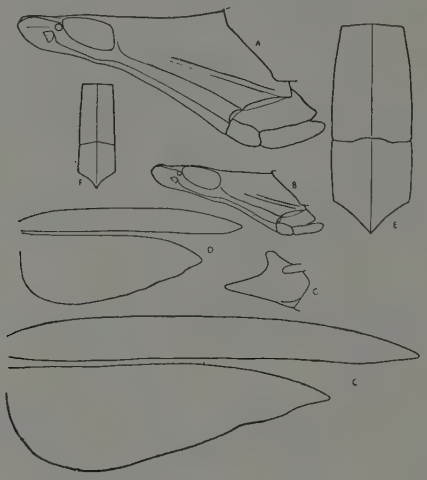


Fig. 17 : *Acrida indica* (letter explanation as in Fig. 1).

Lateral carinae of pronotum, in prozona, slightly convergent forwards, or parallel and straight.

Wing distinctly shorter than elytron. with acute apex

Geographical distribution : India : Nasik, 9.000 ft., ix. 1914, 1 ♂ (Type) ; Bombay, xi. 1915, 1 ♀ (N. B. Kinnear) ; Bombay, 1 ♀ (Fontanier) ; S. India, 1 ♀, « India », 2 ♀♀.

18. Acrida lineata (Thunb.)

1815, *Truxalis lineatus* Thunberg, *Mem. Acad. Sci. St. Petersburg,* V : 266. — 1827, *Truxalis lineatus* Thunberg, *Nova Acta Upsal.,* IX : 85.

Under the name *Tr. lineatus* in Thunberg's collection in the Uppsala Museum there is preserved a single female, in a very poor condition, but it was possible to study all the important characters. In the original description it is stated « Habitat in Morocco », and this led me, in my revision (Dirsh, 1949) to confuse it with *A. turrita* L. When I studied the type and compared it with all the material of the genus, it was found that there is no species in Africa like the type. Only amongst a material from Indo-

China have I found a single female specimen which resembled *A. lineata* Thunberg.

T h u n b e r g ' s specimens have no labels on the pins and it is most probable that T h u n b e r g himself confused material which he collected during his travels in Asia with that from Africa.

♀ (Type) — R e d e s c r i p t i o n : Large and slender

Head strongly elongated and comparatively narrow in the basal part ; frons, in profile, little incurved Antenna comparatively broad and probably shorter than head and pronotum together (apex broken in the type). Fastigium of vertex large, with parallel lateral margins and broadly rounded apex.

Lateral carinae of pronotum, in prozona, almost straight, slightly convergent forwards, in metazona excurved. Transverse sulcus about the middle of pronotal disc ; posterior margin of metazona acutangulate, with strongly acute apex and incurved sides.

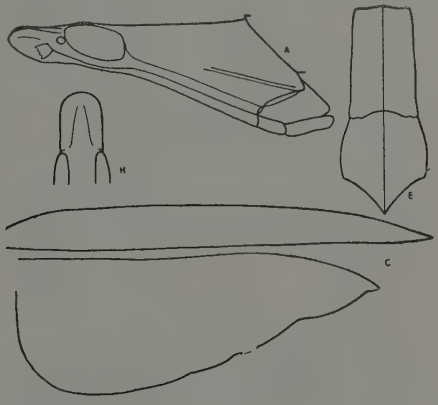


Fig. 18 : *Acrida lineata,* female : (A) head ; (C) elytron and wing ; (E) pronotum ; (H) fastigium of vertex.

Elytron relatively broad, with strongly narrowing and acute apex. Wing broad, with narrow, acute apex.

Lateral lobes of the hind knee moderately long, subacute ; upper lobe broader than lower one.

General colouration light green with light ochraceous lateral stripe along head, from eyes, on the upper margin of pronotum and dorsal part of elytron ; wing light greenish-yellow.

A. lineata Thunb. differs from *A. turrita* L. by more robust head ; broader antenna ; form of lateral carina of pronotum and broader elytra.

G e o g r a p h i c a l d i s t r i b u t i o n : Indo-China. Specimens studied: 2 ♀ ♀

19. Acrida cinerea (Thunb.)

1815, *Truxalis cinereus* Thunberg, *Mem. Acad. Petersb.*, V : 263. — 1827, *Truxalis cinereus* Thunberg, *Nova Acta Upsal.*, IX : 79. — 1815, *Truxalis unicolor* Thunberg, *Mem. Acad. Petersb.*, V : 263. — 1827, *Truxalis unicolor* Thunberg, *Nova Acta Upsal.*, IX : 85. — 1842, *Truxalis chinensis* Westwood, Donovan, Ins. China 22, pl. 10, f. 1. — 1866, *Acrida lata* Motschulsky, *Bull. Sci. Nat. Mosc.*, XXXIX (1) : 181. — 1901, *Acrida csikii* I. Bolivar, 3-tes Asiat. Forschungreise, II : 228, no. 7. — 1913, *Acrida turrita koreana* Ikonnikov, Uber Schmidt aus Korea mitgebr. Acridiodeen, Kuznetzk : 10, f. 1.

Under the name *Tr. cinereus*, in Thunberg's collection is preserved a single male without locality, which I have fixed as specific type. The specimen is in a poor condition, discoloured by the preserving liquid (now dry). After comparing it with all other species studied, it appeared identical with the species occurring in Japan.

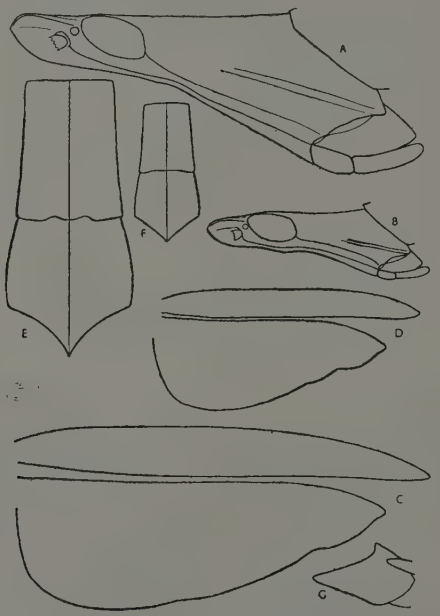


Fig. 19 : *Acrida cinerea* (letter explanation as in Fig. 1).

Tr. unicolor Thunberg, a single specimen in the same collection also without locality, appears to be the female of *cinereus* Thunberg. The first name has priority.

Type of *Tr. chinensis* Westw. is lost, but from the description and particularly two figures this is most probably also *A. cinerea* Thunb.

A. lata Motsch., described by Motschulsky from Japan whence only one species *A. cinerea* is known.

A. csikii I. Bol. was described from « Peking ». Type has not been studied but the description fits *A. cinerea* Thunb.

A turrita koreana Ikon, agrees in the short description with *A. cinerea* Thunb., which is the only species known from Korea.

In 1951 (G. J. Bey-Bienko and L. A. Mistshenko, Acridoidea of the Fauna of U.S.S.R., Moscow), three new species of *Acrida* were described : *A. kozlovi* Mistshenko (Type locality : Dinuanin Ninsya, North China), *A. granulosa* Mistshenko (Type locality : Unzen, Japan) and *A. incallida* Mistshenko (Type locality : Guntzhulin, Manchuria). I have had no opportunity to examine the types, and the descriptions are very short and only in a key. It is probable that these three species may represent local races of *A. cinerea* which is the only species known to me from that region.

♂ (Type). — Redescription : Large and robust.

Head strongly elongated and robust, moderately widened in the base ; frons in profile, moderately concave. Antenna slightly shorter than head and pronotum together. Fastigium of vertex long, with parallel lateral margins and rounded apex.

Lateral carinae of pronotum strongly projecting, in prozona straight, slightly convergent forwards, in metazona slightly excurved and divergent ; deep transverse sulcus slightly before the middle of pronotal disc ; posterior margin of metazona acutangulate, with slightly incurved sides.

Elytron little produced beyond the hind knee, broad, with short apical part and subacute apex ; wing relatively narrow, with narrow apex.

Lateral lobes of the hind knee short, subacute ; upper and lower lobe almost equal in width.

Subgenital plate moderately long with subacute apex, in profile, with strong subacute projection on the upper margin.

♀. — Differs from the male by the following characters : body much larger and much more robust ; head more robust and more widened in the basal part ; posterior margin of metazona of pronotum more acutangulate, with pointed apex ; wing narrower with more narrowed apex.

General colouration varies from uniformly green to yellowish ; wing slightly yellowish.

A. cinerea is an Eastern Asiatic species but is not related to other known species from Asia, the nearest related species being, surprisingly, the South African *A. testacea* Thunb.

This species varies strongly in body size and degree of robustness of body. Japanese specimens are the most robust ; nearest to them are specimens from the coastal zone of China ; specimens from S. Korea are also robust ; but those from inner China and Manchuria are much more slender, and specimens from Mongolia are even more slender. They are all connected by

intermediate forms and may represent local races, possibly of subspecific rank.

Colouration varies from uniformly green to ochraceous or yellowish, sometimes with stripes along head, pronotum and elytron. Wing after moulting, is colourless, but during maturation becomes weakly yellowish and in the sexually mature males the disc of wing becomes infumate 23 ♂♂, 42 ♀♀ were examined.

Geographical distribution : Nippon, Kyushu, Korea, Manchuria, Mongolia, China, Hongkong, Macao, Tsushima Is., Formosa (Map 8).

20. Acrida willemsei sp. n.

♂ (Type). — Of medium size and slender.

Head strongly elongated ; from above and in profile, comparatively narrow in the basal part ; frons, in profile, moderately incurved. Antenna shorter than head and pronotum together. Fastigium of vertex long, with parallel lateral margins and broadly obtusangulate apex.

Lateral carinae of pronotum, in prozona, straight and convergent forwards, in metazona slightly excurved and divergent ; transverse sulcus about

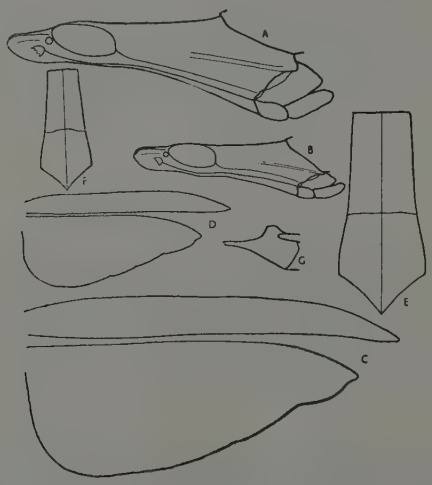


Fig. 20 : *Acrida willemsei* (letter explanation as in Fig. 1).

the middle of pronotal disc ; posterior margin of metazona acutangulate with slightly incurved sides.

Elytron produced a little beyond the hind knee, moderately broad, with short apical part and subacute apex. Wing slightly shorter than elytron, broad with moderately broad apical part.

Lateral lobes of the hind knee short, acute ; upper and lower lobes almost equal in width.

Subgenital plate elongated, with narrow, strongly acute apex, in profile, with large obtuse projection on the upper margin.

General colouration uniformly green ; wing light greenish-yellow, with brownish darkening on the greater part of the disc, except the apical fourth.

♀ (Paratype). — As the male, but larger ; wing less infumate.

This species varies in the following characters : body size, form of pronotal carinae, which in prozona are sometimes parallel, slightly undulated ; in metazona more strongly or less strongly excurved ; elytron at the apex is more or less acute ; subgenital plate of male sometimes less acute than in the type. Colouration varies from green to ochraceous and brownish ; pattern of elytron present chiefly in the females ; darkening of the wing is most developed in sexually mature specimens particularly in the males.

A. willemsei is widely distributed throughout south-eastern Asia, the greater part of the Australasian Archipelago, to the north up to 30° of latitude, but the southern limit is not clear. In this large area with its perfect conditions for isolation the species forms many local races, but specific limits remain definite.

A. willemsei is nearest to *A. exaltata,* but differs strongly by more slender head and more acute and elongated subgenital plate of male. On the other hand, it is near to the Australian *A. conica.*

The species is named after Dr. C. Willemse, who has contributed so much to the knowledge of Orthoptera of this region.

Geographical distribution : Type locality : Sunge : Tua, Knala Lumpur, 5.xiii.1928, type 1 ♂ (N.C.E. Miller). Burma, Siam, Malaya, China, Formosa, Hainan, Philippine Isl., Celebes, Java, Sumatra (Map 8). 159 ♂♂, 126 ♀♀ were examined.

21. Acrida cheesmanae sp. n.

♂ (Type). — Large and slender.

Head strongly elongated and little widened in the basal part ; frons, in profile, weakly incurved. Antenna almost as long as head and pronotum together. Fastigium of vertex moderately long, narrow, with parallel lateral margins and obtusangulate apex.

Lateral carinae of pronotum, in prozona, straight and parallel, in metazona, slightly excurved ; transverse sulcus far behind the middle of pronotal disc ; posterior margin of metazona rectangulate, with slightly incurved sides.

Elytron produced a little beyond the hind knee, narrow, with long, narrowing apical part and acute apex. Wing markedly shorter than elytron, narrow, with narrow apical part.

Lateral lobes of the hind knee short, subacute ; upper and lower lobes almost of equal length.

Subgenital plate long, with strongly elongated and acute apex ; on the upper margin, in profile, a small obtuse projection.

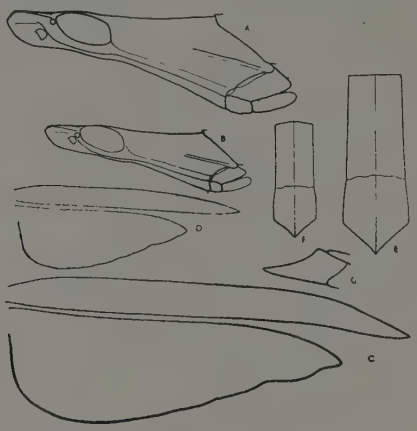


Fig. 21 : *Acrida cheesmanae* (letter explanation as in Fig. 1).

General colouration light green, with ochraceous lateral stripes along the head, from eye, through upper margin of lateral lobe of pronotum and along the dorsal part of elytron ; wing slightly yellowish.

♀. — As the male, but larger.

This species is easy to distinguish from the other by transverse sulcus of pronotum, which is disposed far behind the middle of the disc ; by more slender habitus and slightly shortened elytra. This species is named after Miss Evelyn Cheesman, well known explorer of the Papuan and Polynesian fauna.

Geographical distribution : Papua : Kokoda, 1.200 ft., x.1933, 2 ♂♂ (including type) (E. L. Cheesman). Thursday Is., 22.v.1902, 1 ♂ (Crawford Exp.). vi.1881, 1 ♂ (H. M. S. Alert). Groote Eyland Is. 1 ♂, (N. B. Tindale). Australia : N. Territory, Darwin, 1 ♂ (M. Hart). Queensland : Cairns, 3 ♂♂ and 1 ♀, Coen R. 1 ♂ (Map 8).

22. Acrida conica (F.)

1781, *Truxalis conicus* Fabricius, Spec. Insect. : 352. — 1853, *Truxalis raflesii*, Blanchard, Voy. Pole Sud, Zool. IV : 366, p. 2, f. 3, 4. — 1870, *Tryxalis scitula* Walker, Cat. Derm. Salt., III : no. 7.

This species was described from « Nova Hollandia » and has the notice « Mus. Dom. Banks ». The type, a female, is in the Bank's collection in

the British Museum, The type locality of *T. raflesii* is « Rafles Bay, sur la Côte nord-ouest de la Nouvelle-Guinée », but the second part of the sentence is incorrect, since Raffles Bay is in northern Australia (Coburg Peninsula). The type is lost but the description and figure make it possible to refer north Australian specimens from Port Darwin to this species.

Walker described the female of *Tr. scitula,* but in the British Museum there are four males only under this name, each with « Type » label and

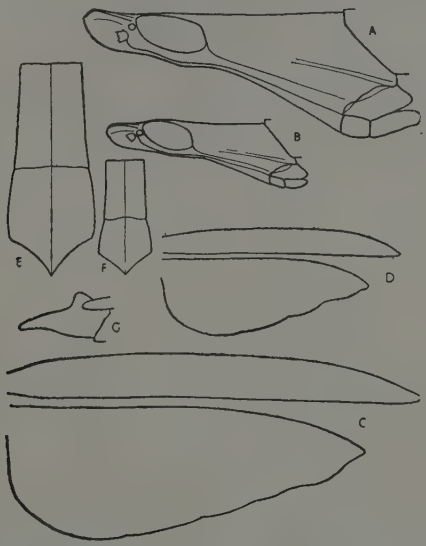


Fig. 22 : *Acrida conica* (letter explanation as in Fig. 1).

labels « One of Walkers series named *T. scitula* », the labels of localities of these specimens are : « Swan River », « Hunter River », « N. Australia », « Australia ». All four are conspecific with *A. conica.* I select as specific type for *A. scitula* Walk. the specimen from « North Australia ».

♀ (Type). — Redescription : Of medium size and slender.

Head elongated, comparatively narrow in the basal part ; frons, in profile, moderately concave. Antenna shorter than head and pronotum together. Fastigium of vertex long, narrow, with parallel lateral margins and broadly obtusangulate apex.

Lateral carinae of pronotum, in prozona, straight, convergent forwards ; in metazona, slightly excurved and slightly divergent ; transverse sulcus about the middle of pronotal disc ; posterior margin of metazona acutangulate, with incurved sides.

Elytron produced well beyond the hind knee, moderately broad, with

short apical part and acute apex. Wing moderately broad with narrow apical part.

Lateral lobes of the hind knee short and subacute ; upper lobe broader than lower one.

General colouration brownish ; elytra with pattern ; wing light yellowish-lemon, slightly infumate.

♂. — As the female, but much smaller. Posterior angle of metazona less acute. Subgenital plate long, with elongated narrow apex and in profile, with a large, obtuse projection in the basal part of the upper margin.

Like other species of the genus it varies in size of body, slightly in the form of lateral carinae of pronotum, and in colouration, which varies from green to brownish, with more or less developed pattern of elytra.

The North and partly West Australian specimens differ strongly from the South and S. East Australian ones by larger size, relatively slender body and more elongated head. Extreme forms in small series may be regarded as a separate species, but after examination of large material, all intermediate forms were found. Probably the N. Australian *A. raflesii* may be regarded as a subspecies of *A. conica*.

A. conica F. is probably nearest to the *A. willemsei*, but differs by the structure of the male subgenital plate. 43 ♂♂, 68 ♀♀ were examined.

Geographical distribution : Whole Australia (Map 8).

23. Acrida carinulata I. Bol.

1889, *Tryxalis carinulata* I. Bolivar, *Jorn. Sci. Lisb.*, (2), I : 90. no. 51.

I have not seen specimens of this species and the type of it probably is lost. The following is Bolivar's full description of it :

« Pallide rufescens (verisimiliter decolorata). Fastigium verticis concavum, marginibus reflexis. Caput supra subtusque longitrorsum carinulatum, inter carinae rugoso-granosum. Antennae modice amplitae. Pronotum granulosum pone sulcum posticum parum ampliatum, carinis punctato-impressis, ante sulcum rectis, parallelis ; pone sulcum laevissime curvatis, valde distantibus ; sulco pone medium sito : margine postico obtuse angulato ; carino media acute producta ; lobis deflexis retrorsum modice ampliatis, margine externe valde incrassato, fere recto, intus carina longitudinali cum carina marginali dorsi parallela, in prozona fere obliterata. Elytra angusta, longissima, valde acuminata vena radiali tertia ante medium elytri furcate, deinde haud ramosa ; vena intercalari basi apiceque obliterata. Alae hyalinae, angustae, acuminatae ; ramo primo venao radialis ante medium alarum furcato. Pectus haud carinatum. Femora antica pronoto breviora ; postica angulis apicalibus dorsalibus modice productis ; arolio magno. ♀. Cabo Verde (Ferreira Borges) ».

Sur un genre nouveau et une espèce nouvelle de Coccoidea-Diaspidini vivant sur *Artemisia* en Iran

(avec 9 Figures)

par M. Kaussari,
Ministère de l'Agriculture du Gouvernement Iranien, Téhéran,
et
par A.S. Balachowsky, Institut Pasteur, Paris

Paragadaspis gen. nov.

Diaspidini-Diaspidina ayant tous les caractères généraux du genre *Gadaspis* Hall (type : *combreti* Hall) ([1] et [2]) dont il se différencie par une ornementation pygidiale simplifiée et les caractères essentiels suivants :

♀ adulte à corps presque circulaire (allongé ou fusiforme chez *Gadaspis* Hall).

L_1 seules présentes, très saillantes, accolées pour former un lobe médian unique (L_1 de même conformation, mais L_2 généralement présentes, bien que réduites, chez *Gadaspis* Hall).

Absence totale d'épines glandulaires pygidiales et prépygidiales (toujours présentes chez *Gadaspis* Hall).

Absence de tubercules glandulaires ventraux dans la zone submarginale des segments abdominaux prépygidiaux ou le métathorax (présents chez *Gadaspis* Hall).

Ouverture anale centrale (basale chez *Gadaspis* Hall).

Glandes circumgénitales totalement absentes (présentes chez *Gadaspis* Hall).

Glandes dorsales et ventrales nombreuses, du même type cylindrique court et étroit (micropores), réparties dans la zone pygidiale et prépygidiale en groupements non coordonnés (présence de macropores dorsaux et de

(1) Hall (W.J.) : On the Ethiopian *Diaspidini* (*Coccoidea*) (*Trans. Roy. Ent. Soc. London*, XCVII, pt. 20, p. 518, 1946).

(2) Le genre *Gadaspis* Hall comprend actuellement 3 espèces africaines tropicales décrites d'Afrique du Sud ou de Rhodésie méridionale (*combreti* Hall, *excisus* Hall et *tuberculata* Hall).

micropores ventraux distincts ; ces premiers sont répartis en groupements coordonnés chez *Gadaspis* Hall).

Les autres caractères sont identiques à ceux du genre *Gadaspis* Hall.

Génotype : *Paragadaspis sarkissiani* n. sp.

Remarques : L'absence totale d'épines glandulaires au pygidium et aux segments prépygidiaux, la structure identique des glandes dorsales et ventrales ainsi que leur répartition incoordonnée, l'absence de glandes circumgénitales, sont autant de caractères importants permettant de distinguer ce nouveau genre du genre *Gadaspis* Hall.

Pour le moment, le genre *Paragadaspis* ne renferme qu'une seule espèce constituant le génotype.

Paragadaspis sarkissiani n. sp.

Bouclier ♀ circulaire ou subcirculaire d'un blanc pur neigeux et mat (fig. 1). Exuvie larvaire légèrement excentrée plus ou moins confondue avec le bouclier ♀, blanche. 1,8 - 1,9 mm.

Puparium ♂ inconnu.

Micro. : ♀ adulte de forme subcirculaire (fig. 2), légèrement retrécie vers l'apex. Cuticule entièrement membraneuse avec un épaississement médiopygidial ventral (fig. 9). Mamelon antennaire petit, subcirculaire, surmonté de 3 soies très courtes (fig. 4). Stigmates antérieures pourvus de 3 à 5 glandes péristigmatiques et de quelques micropores tubulaires (fig. 5). Stigmates postérieurs de même structure (fig. 3).

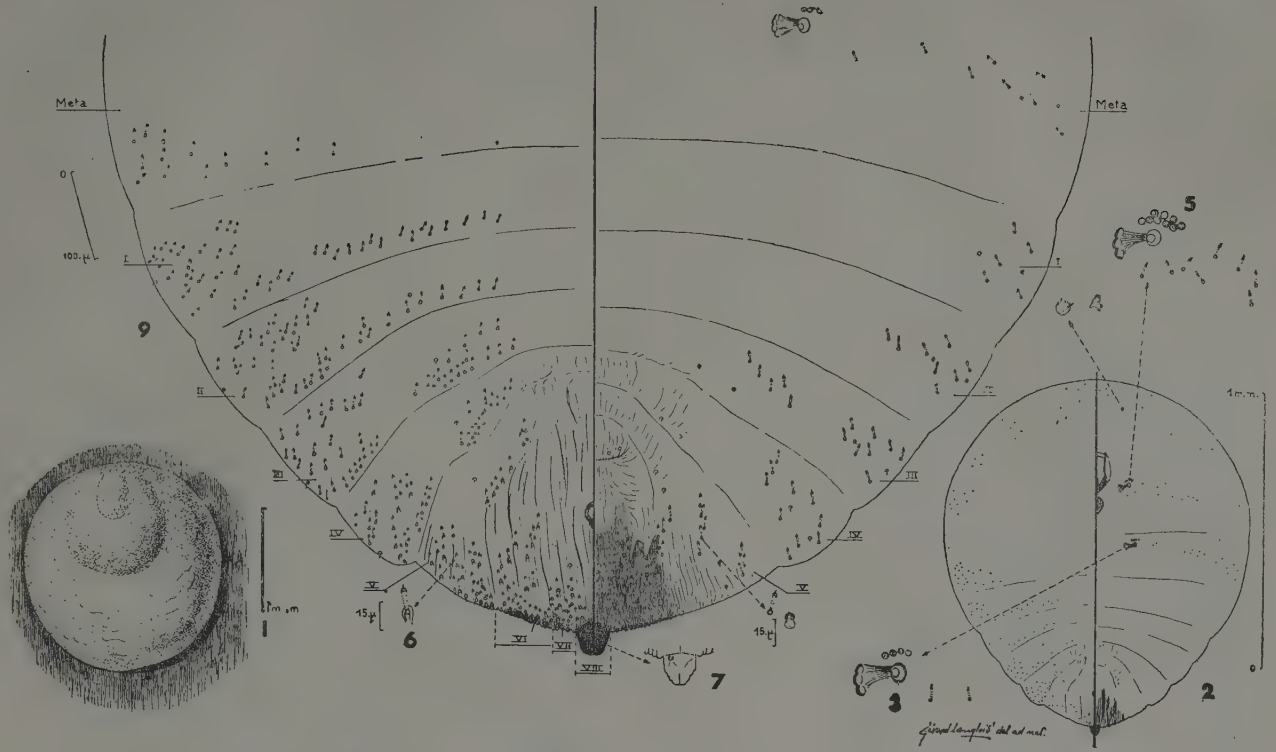
Pygidium large, arrondi, avec la marge apicale presque horizontale (fig. 9), pourvu seulement de L_1 qui sont très saillantes, accolées l'une à l'autre, plus longues que larges (fig. 9), parfois denticulées sur leur marge externe (fig. 7). Absence totale de L_2 et d'épines glandulaires marginales pygidiales ou prépygidiales.

Bordure des segments VI - VII du pygidium fortement épaissie (fig. 9). Soies marginales courtes et peu nombreuses (fig. 9).

Ouverture anale située légèrement en-dessous du centre du pygidium, nettement au-dessus du niveau vulvaire (par transparence), de diamètre circulaire inférieur à la largeur de L_1 et pourtour légèrement chitinisé.

Glandes dorsales du pygidium constituées exclusivement par des micropores tubulaires courts et étroits (fig. 6), réparties dorsalement sur tous les segments pygidiaux et prépygidiaux comme l'indique la fig. 9.

Sur les segments V à VIII, ces micropores forment un groupe dense marginal et submarginal confondu comprenant plus d'une centaine d'éléments de chaque côté. Sur les segments I à IV inclus, les micropores se répartissent en deux groupements, l'un submarginal et l'autre submédian, qui se confondent parfois, surtout sur I et II (fig. 9). Sur le métathorax



Paragadaspis sarkissiani n. sp., ♀ adulte : (1) bouclier de la ♀ adulte ; (2) aspect général ; (3) stigmate postérieur ; (4) antennes ; (5) stigmate antérieur ; (6) micropore dorsal ; (7) variation de L_1 ; (8) micropore ventral ; (9) pygidium. (Planche exécutée par Monsieur Gérard Langlois, Technicien-Dessinateur à l'Institut Pasteur, Paris).

et le mésothorax, les micropores sont plus espacés et ils sont présents également dans la zone pleurale céphalothoracique.

Absence totale de glandes circumgénitales ou de crêtes paragénitales. Micropores ventraux identiques à ceux de la face dorsale (fig. 8), mais répartis d'une manière nettement moins dense (fig. 9), principalement dans la zone submarginale avec quelques éléments submédians prépygidiaux.

Larve néonate : Antennes de 6 articles avec le 6ème sensiblement de même longueur que le 3ème et le 5ème ; 2ème le plus court. Glandes céphaliques jumelées présentes.

Cette larve correspond très nettement à un type *diaspioïde*.

Biologie et habitat : Cette espèce a été découverte en 1953 par M. Sarkissian, à qui elle est dédiée, sur les parties ligneuses d'une Armoise (*Artemisia* sp.) dans le désert salé du centre de l'Iran entre Djandagh et Bianbanak.

Un Buprestide nouveau de l'Oasis de Siwa

[Coleoptera]

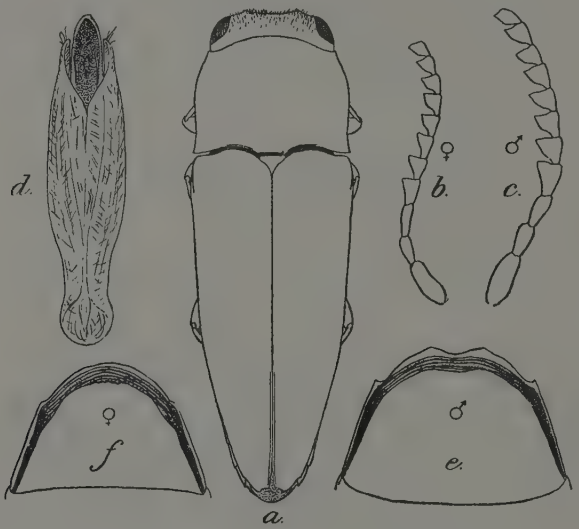
(avec 1 Figure)

par A. Descarpentries,
Museum National d'Histoire Naturelle, Paris

Sphenoptera (Deudora) siwaensis n. sp.

Long. 7.25 à 8.5 mm.; larg. 2.5 à 2.75 mm. — Bronzé cuivreux, brillant, recouvert sur le dessus d'une très fine, courte et éparse pubescence blanche peu visible, plus longue et plus abondante sur la tête et la face ventrale. Epistome échancré en arc, carènes préantennaires saillantes et tranchantes ; front très faiblement sillonné, légèrement impressionné en avant et présentant deux reliefs obliques, situés de part et d'autre de la ligne médiane, en arrière de l'impression ; bords internes des yeux subparallèles ; antennes à 3e article de même longueur que le 4e, les suivants dilatés, subtriangulaires. Pronotum ayant sa plus grande largeur un peu avant le milieu, bisinué et non rebordé en avant, les côtés largement arrondis, avec les angles postérieurs aigus et saillants en dehors, la carène latérale nulle sur le 1/3 antérieur, la base bisinuée, avec le lobe médian tronqué droit devant l'écusson. Disque bombé, sans trace d'impression ni sillon, à ponctuation primaire assez dense, peu profonde, un peu effacée et confuse sur les côtés, microponctuation très superficielle. Ecusson plan, microponctué. Elytres à côtés légèrement dilatés après les épaules, puis subparallèles sur la moitié antérieure, atténués ensuite en ligne presque droite jusqu'à l'apex, l'épine suturale peu développée, les dents médiane et externe très obtuses, la dernière très peu marquée, carène latérale visible jusqu'à celle-ci, suture relevée sur un peu plus du 1/3 postérieur. Disque assez bombé, à sculpture confuse, ridulée en travers, les stries constituées par des traits fins sérialement disposés, chacun au fond d'un point irrégulier et très superficiel ; ponctuation primaire et microponctuation beaucoup plus confuses que sur le pronotum. Prosternum à bord antérieur subdroit et rebordé, strie marginale de la saillie prosternale ne contournant pas le sommet. Metasternum profondément sillonné longitudinalement. Abdomen peu profondément mais assez densément et régulièrement ponctué, sans espace lisse. Dernier sternite visible muni latéralement d'une dent plus ou moins développée, sa marge striolée.

♂ : Antennes à articles médians transverses. Tibias médians sinués le long du bord interne, la dent apicale peu aiguë, celle, préapicale des tibias postérieurs, encore plus réduite. Dernier sternite visible subsinué au sommet. Aedeagus noir brunâtre, assez court et large ; pénis large au sommet, très faiblement dilaté à l'extrême apex, profondément excavé sur la face ventrale ; paramères sans sinuosité apicale (fig. *c, d, e*).



Sphenoptera (*Deudora*) *siwaensis* n. sp. : *a.*, contour du corps ; *b.* et *c.*, antennes femelle et mâle ; *d.*, édéage (face ventrale) ; *e.* et *f.*, derniers sternites visibles mâle et femelle.

♀ : Antennes à articles médians moins transverses. Tibias médians plus grêles, à bord interne moins sinué, dépourvus de dent apicale. Dernier sternite visible arrondi au sommet (fig. *b, f*).

Holotype ♂ et allotype : Khamissa (Egypte : Oasis de Siwa), 22.vi.1935 (J. Omer-Cooper, coll. British Museum).

Honey flows in Giza Region

(with 5 Tables and 4 Figures)

by A.K.M. El-Nahal,
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INTRODUCTION

The variation of honey flows and their sources according to regions has given rise to different apiary practices. The most important of these practices is the manipulation of the colonies so that they might, at the right moment, have the proper strength and composition for gathering a maximum honey crop during the honey flow. It is appropriate, therefore, to know the periods of these honey flows, and then to modify brood rearing activity so that it may take place at a proper time before any given honey flow.

There are soil, climatic and agricultural differences between the different regions of Egypt, and some variations in the characteristics of the honey flows in these regions should be expected. It is necessary, therefore, to investigate the honey flows in each of these regions separately. This work is an investigation of the honey flows in Giza Region. It was carried out during the two seasons of 1944 and 1945.

METHODS

In February 1944, seven normal colonies (marked 1 to 7) were chosen in typical single walled Langstroth hives. Each colony had its vigorous laying queen, sufficient number of workers and sufficient stores. The weights of these colonies were taken every five days in the morning before the bees leave their hives to the field. They were not in any way manipulated for the purpose of changing their storing capacity except that enough room was given by the addition of frames or supers. The records are, therefore, largely a presentation of what bees, do without the interference of the beekeeper. In order to obtain the net gains and net losses in the weight of each colony, everything that was to be added to or taken from it was first weighed.

In February 1945 two of these seven colonies (Nos. 1 and 2) were selected and 5 others (marked 10-14) were added. They were manipulated and their records were taken in the same way as was done in the season of 1944.

For each of all these colonies, the net losses and gains and the change in weight in periods of five days from March 15th till October 15th were determined.

RESULTS

1. Weight records of two Colonies (No. 1 and 2) for two successive seasons.

As mentioned above colonies No. 1 and 2 were chosen as normal and typical to be studied during the two successive seasons of 1944 and 1945. The

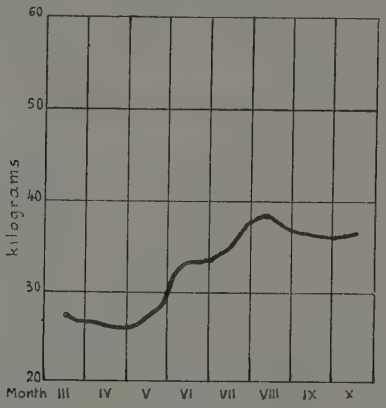

Fig. 1 : Curve showing change of weight of Colony No. 1, 1944.

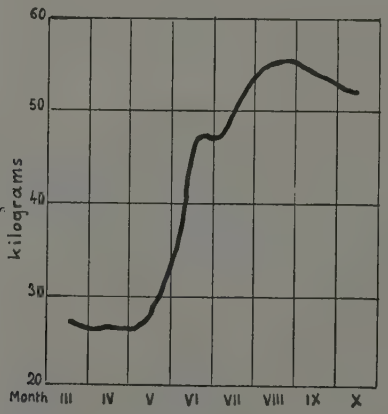

Fig. 2 : Curve showing change of weight of Colony No. 1, 1945.

net losses and gains in their weights for the two seasons are shown in Tables I to IV, and the changes in their weights are shown graphically in Figs. 1 to 4.

Colony No. 1, 1944 (Table I and Fig. 1)

The loss in weight continued from March 15th till May 1st, when the first honey from the Egyptian clover began to be stored. From this date on, the increase in weight continued till the first five days of August with a

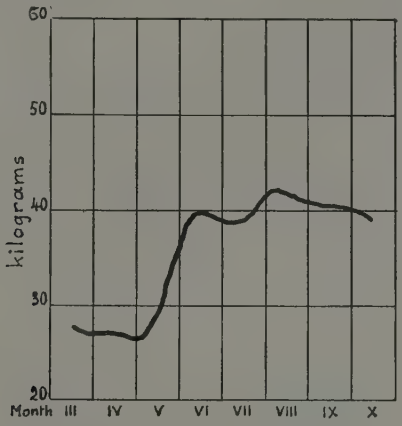

Fig. 3 : Curve showing change of weight of Colony No. 2, 1944.

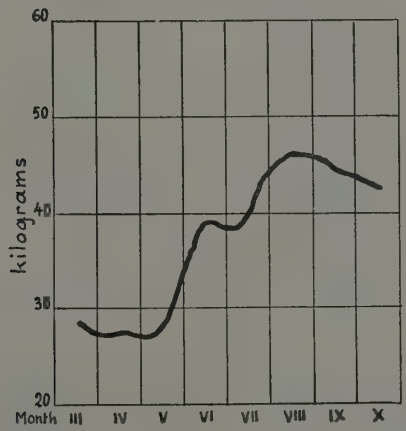

Fig. 4 : Curve showing change of weight of Colony No. 2, 1945.

little period of interruption from 15-25th of June. From August 5th no increase in weight took place till October 15th.

Colony No. 1, 1945 (Table II and Fig. 2)

In 1945 a period of increase in weight took place during the ten days from 10-20 April. The increase in weight again began from May 1st and continued till August 15th with a period of interruption also from only 20-25

TABLE I

Net gains and net losses of weight of Colony No. 1, 1944

DATE	MARCH		APRIL		MAY		JUNE		JULY		AUGUST		SEPTEMBER		OCTOBER	
	+	—	+	—	+	—	+	—	+	—	+	—	+	—	+	—
1- 5			—	—	0.075	—	0.20	—	0.45	—	0.50	—	—	0.20	—	—
5-10			—	0.05	0.225	—	1.95	—	0.55	—	—	—	—	0.10	—	0.15
10-15			—	0.15	0.300	—	0.40	—	0.50	—	—	—	—	0.15	—	0.01
15-20	—	0.375	—	0.35	1.850	—	—	0.15	0.65	—	—	0.80	—	—		
20-25	—	0.175	—	0.05	1.000	—	—	0.10	1.45	—	—	0.30	—	—		
25-30	—	0.150	—	0.10	0.900	—	0.35	—	1.00	—	—	0.30	—	0.20		

TABLE II

Net gains and net losses of weight of Colony No. 1, 1945

DATE	MARCH		APRIL		MAY		JUNE		JULY		AUGUST		SEPTEMBER		OCTOBER	
	+	—	+	—	+	—	+	—	+	—	+	—	+	—	+	—
1- 5			—	—	0.25	—	4.00	—	0.40	—	0.40	—	—	0.50	—	0.25
5-10			—	—	0.10	—	3.00	—	1.00	—	0.45	—	—	0.75	—	0.10
10-15			0.25	—	1.40	—	7.50	—	1.45	—	0.30	—	—	0.25	—	0.30
15-20	—	0.600	0.30	—	1.10	—	0.65	—	2.35	—	—	0.20	—	0.25		
20-25	—	0.325	—	0.25	2.00	—	—	0.35	1.25	—	—	0.05	—	0.20		
25-30	—	0.250	—	0.30	2.10	—	0.10	—	0.85	—	—	—	—	0.40		

Table III

Net gains and net losses of weight of Colony No. 2, 1944

DATE	MARCH		APRIL		MAY		JUNE		JULY		AUGUST		SEPTEMBER		OCTOBER	
	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−
1- 5			—	—	0.250	—	2.80	—	—	0.25	0.50	—	—	0.20	—	0.10
5-10			—	—	0.500	—	2.15	—	—	—	—	—	—	0.15	—	0.10
10-15			—	—	1.100	—	0.50	—	—	—	—	—	—	0.15	—	0.55
15-20	—	0.475	—	0.25	3.975	—	—	0 30	0.40	—	—	0.450	—	0.20		
20-25	—	—	—	—	1.400	—	—	0.45	1.05	—	—	0.075	—	0.20		
25-30	—	0.100	—	0.25	1.000	—	—	0.20	1.05	—	—	0.075	—	0.10		

Table IV

Net gains and net losses of weight of Colony No. 2, 1945

DATE	MARCH		APRIL		MAY		JUNE		JULY		AUGUST		SEPTEMBER		OCTOBER	
	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−
1- 5			—	0.15	0.20	—	2.70	—	—	—	0.95	—	—	0.40	—	0.45
5-10			—	0.05	0.15	—	1.65	—	0.60	—	0.20	—	—	0.25	—	0 05
10-15			0.15	—	1.55	—	1 60	—	1.90	—	0.20	—	—	0.25	—	0 40
15-20	—	0.450	0.20	—	0.85	—	—	0.15	2.25	—	—	0.45	—	0.40		
20-25	—	0.225	—	0.35	2.00	—	—	0.70	1.55	—	—	0.10	—	0.15		
25-30	—	0 250	—	0.15	2.15	—	—	0 30	0.85	—	—	0.30	—	0.65		

June. The loss in weight again continued from August 15th till October 15th. During this season the crop of honey was more profitable than the last season.

Colony No. 2, 1944 (Table III and Fig 3)

The weight of this colony was constant throughout April except some slight loss during the periods from 15 to 20 and 25 to 30 April. The storing of honey began from May 1st and continued normally till June 15th when the period of interruption commenced. From that date on, the records of this colony became unsatisfactory. Unlike the case of the other colonies, there was too wide a gap of loss in weight which continued from June 15th till July 5th, followed by another period of ten days in which the weight remained constant. The quantity of honey stored after this period till August 5th was little in general.

Colony No. 2, 1945 (Table IV and Fig. 4)

This colony began its main season from May 1st till August 5th. The gap of decrease in weight lasted 15 days from 15-30 June followed by five days of constant weight from 1st to 5th July. Some honey also was stored during the period from 10th to 20th April.

TABLE V

The total increase in weight in kilograms of the Colonies of the experiment and the increase in each period separately

NUMBER OF COLONY	SEASON	PERIODS OF INCREASE	TOTAL INCREASE	INCREASE IN THE FIRST PERIOD	INCREASE IN THE SECOND PERIOD
1	1944	1. V - 15. VI and 25. VI. - 5. VIII	13.350	7.900	5.450
2	»	1. V - 15. VI » 15. VII - 5. VIII	16.675	13.675	3.000
3	»	20. IV - 15. VI » 25. VI - 5. VIII	28.925	21 925	7.000
4	»	20. IV - 15. VI » 5. VII - 5. VIII	21 890	17.140	4.750
5	»	25. IV - 15. VI » 1. VII - 5. VIII	32.700	23.200	9.500
6	»	1. V - 15. VI » 5. VII - 5. VIII	10 300	7 900	2.400
7	»	1. V - 15. VI » 5. VII - 5. VIII	20.850	16.750	4.100
1	1945	1. V - 20. VI » 25. VI - 15. VIII	30.650	22 100	8.550
2	»	1. V - 15. VI » 5. VII - 15. VIII	21.350	12.850	8.500
10	»	1. V - 15. VI » 5. VII - 5. VIII	21.850	16 500	5 200
11	»	1. V - 20. VI » 5. VII - 15. VIII	30.750	20.750	10.000
12	»	1. V - 15. VI » 1. VII - 15. VIII	53.950	31.100	22.850
13	»	1. V - 20. VI » 1. VII - 15. VIII	35.850	25.850	10.000
14	»	10. V - 15. VI » 5. VII - 30. VII	9.750	7.800	1.950

2. General observations on the weight records of the remaining colonies.

In general, the weight records of the remaining colonies in 1944 were the same as colonies No. 1 and 2 mentioned above. No honey was stored

during April. The main period of honey storage was during the months of May, June, July and few days in August, with a period of loss in weight from about June 15th till 25th. There are some variations between the records of these colonies due mainly to special internal conditions in each colony i.e. the activity of the queen and the number of honey gathering force.

In the season of 1945, climatic conditions were so favourable. All the colonies showed some increase in weight during this month due to honey gathered from citrus bloom, from which no surplus honey was stored in the previous year. This early honey was a good stimulus for obtaining a good honey crop during the main honey flows of May, June, July and August.

DISCUSSION

Although the records of every season seem to show little correlation, they, however, reveal definite relationships. The apparent differences resulted from special conditions within individual colonies, which caused modifications in the storing responses. On the whole, the records point to certain more or less two definite periods of honey production due to nectar flows in the fields. The first period begins from May 1st and ends in June 15th, the second from July 1st till August 10-15th, with slight fluctuations in these dates owing to special conditions within the individual colonies and changes in weather conditions from season to season.

In the first period the Egyptian clover is the chief source. The increase in weight during the clover honeyflow begins generally from May 1st and sometimes from April 25th, or 20th, but this increase continues slowly until about May 10-15th when considerable quantities are stored in the hives till about June 15-20th, when the increase falls abruptly to nothing, showing the close of the clover nectar flow. The period from May 10th to June 15th may be considered as the chief period during the clover honey flow.

The chief source of nectar during the second period is the cotton plant. The quantity of honey stored in this period during the two seasons of 1944 and 1945 was found to be less than in the first period. In order to throw some light on this fact, Table V shows the total increase in weight of each colony during these two periods and the increase in each period separately.

The chief source during April is citrus bloom, but this is not a source of surplus especially when weather conditions during the blooming period are unfavourable as it happened in 1944. The importance of this early source is that it comes during the time of the brood-rearing activity period prior to the main honey flows of the year.

On the light of the resutls of the present work the following practices may be valuable for producing a good honey crop.

(1) Every colony in the apiary should be controlled so as to have a maximum surplus population of field bees during the whole period of storing honey from May 1st till August 15th. In order to have this condition, the highest daily rate of bees emerging from the brood cells should occur about three weeks before May 1st. This is based on the fact that a young worker bee spends the first two to three weeks of her life in duties within the hive before serving as nectar gatherers (Fillips and Demuth 1922, and Nolan, 1925). Since the development of the worker bee requires about three weeks, the queen shoud reach her maximum daily egg-laying rate 6-8 weeks before May 1st.

(2) Egg-laying should continue without any interruption during a period not later than the first of March till the beginning of the honey flow in about May 1st. Every colony, during this period, should have its vigorous laying queen, abundant stores and sufficient space for egg-laying. At this time the citrus and decidious bloom encourage the colonies to quickly build up to full strength.

(3) When swarming occurs before March 1st, conditions should be prepared for the parent colony and the swarm to build up to full strength before May 1st. If the main purpose of the apiary is surplus honey, dividing of colonies should be prevented from March 1st so that the divided colonies might gain strength before the beginning of the clover honey flow.

(4) Since the honey flow from clover has been shown to be rapid and abundant, it is necessary that extra room should be given otherwise some of the nectar flow might be missed. Dividing of colonies or allowing them to natural swarming during the honey flow results in a decrease in the honey crop.

(5) When removing the clover honey crop in about June 15th, an abundance of honey should be left for the bees so that brood-rearing may go on with as little interruption as possible during the cotton honey flow from June 20th till August 15th.

(6) At the end of the active season from August 15th conditions should be provided for the colonies to rear their winter bees. Each colony should have its vigorous laying queen previous to August 15th, and abundant stores must be left in the hives. During the fall and winter months, the bees gather some nectar and pollen from some minor sources, especially the pollen of Indian corn (*Zea mays*) during September and October.

CONCLUSIONS

There are two main honey flows in Giza Region, the Egyptian clover honey flow and the cotton honey flow. The first continues from about May 1st till about June 15th, and the second from about July 1st till August 15th.

During the two seasons investigated, the increase in weight of bee hives during the 1st honey flow was found to be more than the increase during the second honey flow. If weather conditions are favourable, some surplus honey is gathered during April from citrus bloom.

Preparation of colonies for these honey flows should begin from about March 1st. The highest rate of daily egg-laying should start from that date and continues without any interruption till the beginning of May.

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Tests on the poisonous effect on honeybees of some insecticides used for plant protection in Egypt

(with 4 Text-Figures and 9 Tables)

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INTRODUCTION

The widespread applications of insecticides on cotton plant for the control of the cotton leaf-worm *Prodenia litura* F. has manifested great danger to the honeybee and other beneficial pollinating insects.

The insecticides mainly in Egypt at present are calcium arsenate, a mixture of lime + sulphur + calcium arsenate, the so-called cotton dust (DDT + γBHC + sulphur), Benzene hexachloride γBHC and DDT.

The honeybee is the most beneficial agent in the pollination of a majority of our seed crops, fruits and vegetables.

A survey of the literature shows increasing losses of bees from poisonning with insecticides. Thompson (1881) observed that bees were killed after Paris green had been sprayed on pear trees in full bloom. In 1892 lead arsenate became the leading stomach poison for insect control and its use for control of the codling moth on fruit trees caused great losses, better control of codling moth resulted when the growers applied insecticides before or after the blooming period.

New source of poisoning for the honeybee resulted by the application of calcium arsenate on cotton. Bishop (1923) reported that in Nova Scotia dry dusting of calcium arsenate caused more damage to bees than did spraying. Hilgendorff and Borchert (1926) reported that the applications of insecticides by airplane had raised protests from beekeepers and serious losses to bees were caused by the application of arsenicals.

McIndo and Demuth (1926) found a difference in death rate when different forms of arsenic were used. The arsenites were more toxic than the arsenates.

Hoskins and Harrison (1934) had shown that sublethal amounts of arsenic will shorten the life of bees.

Weissmann (1942) carried out his experiments with DDT and concluded that Gesarol spray was more powerful as contact insecticide than a stomach poison to the honeybee, but the work of Holst (1944) produced contradictory results showing that DDT was contact poison at 1 % but not at 0.05 % while, fed in sirup, it acted as stomach poison at 0.05 %. A series of experiments on the contact effect of DDT films were carried out by Filmer and Smith (1944) who found that 20-30 minutes exposures to deposits on glass plates varying from 0.01 to 0.4 mgs DDT per square inch gave a high kill to honeybees within three hours.

Eckerts experiments (1945) on the treatments of the combs of a hive with 3 % DDT dust showed no permanent injury, whereas similar treatment with 20 % DDT caused destruction of the queen and removal of larvae but not causing undue loss of workers, or nurse bees.

Cherian and Mahadevan (1946) dusted the inside of a hive of indian bees *Apis indica,* with 1 % gammexane dust, which caused complete mortality to the bees in six days, while with DDT dust caused death of all bees in 10 hours. DDT dust containing less than 5 % DDT was not injurious, but 10 % DDT has the same effect as 5 % gammexane dust.

McGregor, Caster, Marvin and Forst (1947) discussed bee poisoning with arsenicals, drift of applied arsenicals, normal and lethal doses of arsenic per bee, arsenicals content of pollen and bee brood. Their observations indicated that colonies dusted directly by airplane with 7.5 % Paris green were not damaged, and a colony was not injured when exposed to drifting dust from cotton field dusted with 15 % calcium arsenate. Evidence showed that the sulphur in the dust did not damage bees and had no repellent effect on them. Bees collected in cotton fields sixteen days after a 7.5 % Paris green dust had been applied had high arsenical content. Two samples of poisoned pollen were taken from combs of colonies more than one mile from fields dusted with the arsenicals. More than 0.1 AS_2 O_3 in larvae or pupae and 0.3 microgram in adult bees indicated poisoning. The arsenic content of bees continued to be high for months in hives containing stored pollen of high arsenic content.

McGregor and Vorhies (1947) performed extensive tests with DDT on cotton, finding that several airplane dustings of bees confined in cages caused complete mortality in seven hours. Less severely exposed bees recovered after showing nervous symptoms for one hour. Field applications of 5 % DDT dust of 20 pound per acre affected few bees and weakened the colonies temporarily, although it did not permanently injure the colonies. The authors concluded that large scale dusting of DDT to cotton is not hazardous to commercial beekeeping.

Way and Synge (1948) carried out laboratory and field experiments

to determine the effect of DDT and benzene hexachloride on honeybees. Laboratory experiments showed that γBHC is a powerful contact and stomach poison, and results of field experiments with commercial preparations confirmed its danger to the foraging bee population. In the laboratory DDT has a contact action at fairly high concentrations, and in the field commercial preparations on open blossoms were apparently harmless to foraging bees.

Todd and Lieberman (1949) performed an experiment to test the effect on honeybees of dusting flowers of alfalfa with 3 % DDT, 5 % chlordane, 1 % parathion, 10 % toxaphene. Parathion killed 40% of visitors, DDT 28 %, chlordane 23 %, and the mortalities in two tests with toxaphene were 8 and 2 %.

Observations of Eckert (1949) had indicated that dichlorodiphenyl dichloroethane (DDD) under field conditions caused no appreciable injury to the populations of colonies and DDT has been injurious to the field force of colonies only when used on alfalfa in full bloom. Chlordane dusts had reduced the field force of colonies by from 50 to 80 % when applied to alfalfa in chlordane in oil caused the loss of brood and a portion of the bees when applied in hot weather as an oil spray to grass, in front of 30 colonies. The bees apparently pulled the fumes through the hives by their ventilating operations. Toxaphene, dichlorodiphenyl dichloroethane and DDT would appear to be safe chemicals when used in minimum quantities of 1.5 pounds per acre, especially when applied when bees are not flying and plants are not in bloom.

Hafliger (1950) tested the comparative toxicity of various insecticides to the honeybee. DDT had proved to be much less toxic in agriculture use than certain laboratory tests at 20°C. Calcium arsenate seemed to be more toxic at higher temperatures, its poisonous action on bees developed very slowly. Benzene hexachloride when compared with DDT suspension proved to be 100 to 250 times more toxic in the normal biological range.

Weaver's experiments (1950) on bees who were allowed to work on rows of flowering cotton inside large cages, showed that mortality was high when bees were left in cages for more than three weeks. The safest of the dusts tested was one contained 20 % toxaphene + 40 % sulphur which resulted in negligible death on all days, with little variations between applications. Dust containing 10 % DDT or chlordane with 40 % sulphur were more toxic, but did not cause highly mortality. Bees were repelled from the cotton for about 3 hours after the applications of a mixture containing 3 % γBHC + 5 % DDT + 40 % sulphur and mortality from this material was slight. Preliminary tests with parathion may be more toxic to bees than any of the organic insecticides.

MATERIAL AND METHODS IN LABORATORY EXPERIMENTS

Experiments were conducted at the Faculty of Agriculture, Ibrahim Pasha University, at Shebin El-Kom, with adult worker honeybees of unknown age, from the Apiary of the Entomology Department. Bees were collected either from the alighting board of the hive or from the feeding hole in the crown board.

Honeybees were placed in cages 15×15×7 cms. (Fig. 1), made of wooden frames with gauze covered ventilation holes. The two large walls were of glass or enamled wire screen.

Methods

(1) Contact poison experiments

(a) The toxicity of several commercial preparations provided through the courtesy of the Imperial Chemical Industries, viz : Cotton dust (DDT 10 % + 25 % of 3 % gamma isomer γBHC + 40 % sulphur + inert substances 25 %), Agrocide 3 (0.65 % W/W gamma isomer γBHC), Agrocide 7 (2.5 % W/W gamma isomer γBHC), Gammexane D.034 gamma isomer content 0.5 % γBHC, and different concentrations of DDT as contact poisons were determined by direct dusting of bees. Dusts were applied from

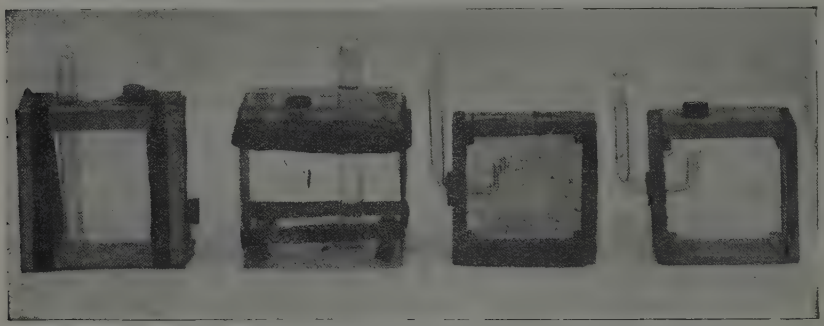

Fig. 1 : Cages used in laboratory experiments with bees.

small dusters with the required concentrations of the insecticides on bees in cages or poured into the cages on the bees, and then distributed by shaking the cages.

(b) The effect of insecticide films were tested by removing the glass walls to be sprayed with a film of the required insecticide, the films allowed to dry and the glass walls were, then put back into the cages which were stocked with bees.

Analysis of results

Table I gives results of dusting caged bees with cotton dust. The bees at first reacted violently to the treatment, becoming extremly active after dusting, then became paralysed and finally died. All the bees were moribund and dead within one hour after the treatment. In cotton dust. dusted cages that were re-stocked with bees three days after the first treat-

TABLE I

Mortality of bees in cages dusted with cotton dust 200 mgs.

TREATMENT	CAGES NUMBER	BEES NUMBER	PERCENTAGE OF MORTALITY IN				
			1 DAY	2 DAYS	3 DAYS	4 DAYS	5 DAYS
Bees dusted with cotton dust	4	148	100	—	—	—	—
Cages re-stocked with bees after three days without further treatment	4	172	69.2	100	—	—	—
Cages re-stocked for the second time after 7 days without further treatment	4	132	59.8	100	—	—	—
CHECKS :							
Bees in cages heavely dusted with talc	3	111	0.9	0.9	2.7	2.7	3.6
Undusted bees	3	117	—	0.85	0.85	2.6	2.6

ment, and without any further dusting all the bees were dead within two days. These cages were again re-stocked seven days after the first treatment and the mortality of bees was 100 % on the second day of re-stocking.

The tests summarised in Table II were designed to show the effect of dusting caged bees with 10 % DDT. All the dusted bees were killed within two hours. Re-stocked bees three days after dusting were killed within two

TABLE II

Mortality of bees in cages dusted with 200 mgs. DDT 10 %

TREATMENT	CAGES NUMBER	BEES NRMBER	PERCENTAGE OF MORTALITY IN				
			1 DAY	2 DAYS	3 DAYS	4 DAYS	5 DAYS
Dusted with 10 % DDT.	3	172	100	—	—	—	—
Re-stocked with bees after 3 days without further treatment	3	165	55.2	100	—	—	—
Re-stocked with bees after 7 days without further treatment	3	136	4.4	5.9	7.4	7.4	8.9
CHECKS :							
Bees heavily dusted with talc	2	86	1.2	2.3	2.3	4.6	5.5
Undusted bees	2	93	—	2.1	2.1	4.3	4.3

days. Further restocking seven days after dusting showed no significant variation from the control bees.

An experiment was designed to investigate the concentration of DDT dust which would not be harmful to honeybees. As shown in Table III different concentrations of DDT were applied directly on caged bees. There were no significant differences between bees in cages dusted with 0.1, 0.25 and 1 % DDT and the control caged bees. The data also shows that these concentrations are harmless to honeybees and could be applied safely in

TABLE III

Mortality of bees dusted with 250 mgs. DDT in various concentrations

(5 cages used in each test)

CONCENTRATIONS OF DDT. %	NUMBFR OF BEES	PERCENTAGE OF MORTALITY IN				
		1 DAY	2 DAYS	3 DAYS	4 DAYS	5 DAYS
0.10	312	1.92	2.60	2.60	3.84	3.84
0.25	287	3.48	3.48	4.20	4.20	4.90
1.00	293	4.40	6 50	6.50	7.50	7.50
2.50	317	16.60	31.80	51.03	51.97	54.10
5.00	279	75.20	100.00	—	—	—
10.00	263	100.00	—	—	—	—
CONTROLS	312	1.6	2.2	2.2	3.84	4.48

the blooming fields. Dusting 2.5 % DDT to caged bees caused 16.6 % mortality on the first day, 54.1 % on the fifth day. The data also shows that 5-10 % DDT dust is very toxic to bees, 5 % dust caused 100 % mortality of all the bees under the experiment on the first day.

TABLE IV

Mortality of bees caused by direct dusting with 250 mgs. of commercial preparations of benzene hexachloride :

(1) Agrocide 3 gamma isomer content W/W 0.65 % ; (2) Agrocide 7 gamma isomer content W/W 2.5 % ; and (3) Gammexane gamma isomer content 0.5 % D.034.

TREATMENT	CAGES NUMBER	BEES NUMBER	PERCENTAGE OF MORTALITY IN				
			1 DAY	2 DAYS	3 DAYS	4 DAYS	5 DAYS
Bees dusted with Agrocide 3	3	163	100	—	—	—	—
Dusted cages re-stocked after 7 days without further treatment ..	3	141	70.9	100	—	—	—
Bees dusted with Agrocide 7	2	106	100	—	—	—	—
Dusted cages re-stocked after 7 days without further treatment ..	2	112	100	—	—	—	—
Bees dusted with Gammexane D.304.	2	107	100	35.4	39.04	—	—
Dusted cages re-stocked after 7 days without further treatment ..	2	82	26.8			41.5	43.9
CHECKS :							
Bees dusted with talc	3	163	0.60	3.70	3.70	6.10	6.10
Undusted bees	3	143	1.38	1.38	2.80	2.80	6.20

Table IV shows the results of dusting with 250 mg. commercial preparations of benzine hexachloride, Agrocide 3, content W/W y gamma isomer 0.65, Agrocide 7 of gamma isomer content of W/W 2.5 % and D.035 gamma isomer content 0.5 %. All preprations are highly toxic to bees and caused mortality of all bees on the first day from the treatment. All bees were killed within one hour after dusting. Re-stocked cages seven days after the treatment showed that all bees were killed on the first day in the case of Agrocide 7 and on the second day in the case of Agrocide 3. Restocked

TABLE V

Mortality of bees in cages having the floor dusted with 50 mgs. :

(1) cotton dust, (2) DDT 10 %, (3) benzene hexachloride gamma isomer W/W 2.5 %, (4) benzene hexachloride gamma isomer W/W 0.65 %.

TREATMENT	CAGES NUMBER	BEES NUMBER	PERCENTAGE OF MORTALITY IN				
			1 DAY	2 DAYS	3 DAYS	4 DAYS	5 DAYS
Floor dusted with cotton dust	3	176	100	—	—	—	—
Floor dusted with DDT. 10 %	3	121	100	—	—	—	—
Floor dusted with yBHC 2.5 % ..	3	132	100	—	—	—	—
Floor dusted with yBHC 0.65 % ..	3	141	100	—	—	—	—
Untreated checks	5	236	1.2	1.2	3.4	3.8	4.7

cages dusted with Gammexane D.034 seven days after the treatment caused mortality of 43.9 % within five days from re-stocking the cages with bees.

This experiment proves that dusting benzene hexachloride at gamma isomer of 0.5, 0.65 and 2.5 % is highly toxic to honeybees.

The experiments summarized in Table V show the effect of dusting the floor of the cages with 50 mg. of one of the following insecticides :

TABLE VI

Mortality of bees in cages having glass walls sprayed with different concentrations of DDT and yBHC

(films on glass)

TREATMENT	CAGES NUMBER	BEES NUMBER	PERCENTAGE OF MORTALITY IN		
			1 DAY	2 DAYS	5 DAYS
DDT %					
0:10	2	112	6.9	14.7	19.6
0.25	2	121	41.8	69.7	72.2
0.50	2	107	90.2	100.0	—
1.00	2	114	100.0	-	—
BHC					
(% y-isomer)					
0.0065	2	93	100.0	—	—
0.0032	2	103	100.0	—	—
0.0016	2	117	36.1	43.4	47.0
0.0004	2	87	5.7	6.8	9.1
Untreated checks	6	324	1.9	3.4	4.9

cotton dust, 10 % DDT and γBHC 2.5 % gamma isomer and γBHC 0.65 % gamma isomer. All the caged bees which were allowed to come in contact with the dusted floor died within 24 hours.

Table VI gives results of the relation of spray dosage and the mortality of bees exposed to the residue of DDT and γBHC. DDT at 0.1 % concentration caused 19.0% kill on the fifth day, whereas concentration of 0.25 % caused 41.8 % kill on the first day and 72.2 % on the fifth day. Concentrations of 0.5 and 1 % were highly toxic to bees, 0.5 % killed all bees on the second day of exposure, and 1 % killed them all on the first day. Concentrations of 0.1 % of DDT spray are comparatively safer for bees than 0.25 and 1 %. Benzene hexachloride as a spray at concentrations of 0.0065 and 0.0032 were generally very toxic to bees and caused the death of all bees with exposures of 10-20 minutes.

(2) Stomach poison experiments

Technical samples of the toxic materials were used in the preparations of all materials used for feeding. Solutions were made in 95 % ethyl alcohol

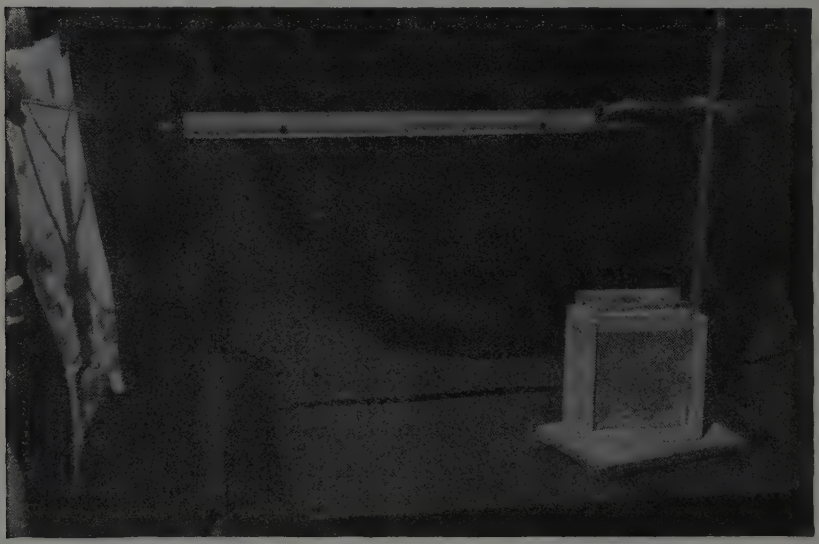

Fig. 2 : Apparatus used for feeding bees individually with known doses of insecticides.

by dissolving known weight of materials in a given amount ol alcohol at laboratory temperature and then pour in the solution in the cold sugar sirup.

The calcium arsenate suspended in a medium containing 1% w/v casein as suspensory agent (Butler, Finney and Schiele 1943). Then specific amount of these stock solution were added to definite amount of sugar sirup 50 %.

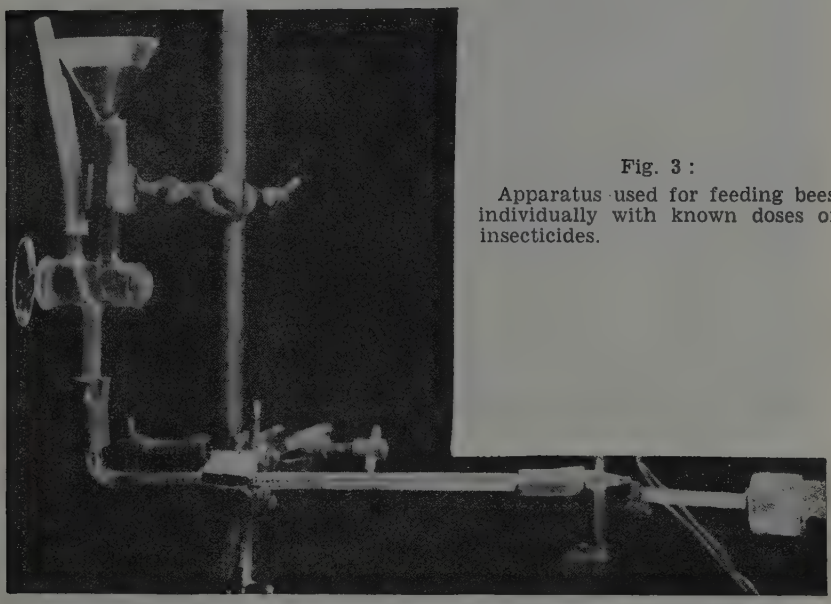

Fig. 3 :
Apparatus used for feeding bees individually with known doses of insecticides.

Different concentrations of insecticides (DDT, benzene hexachloride and calcium arsenate) were used and were fed to bees individually.

The technique of Way and Synge 1948, was used. Bees were fed individually with known volume of the insecticide. Micropipette of capillary tubing was used for feeding bees individually (Figs. 2 and 3). Five concentrations of each insecticide were used and twenty to thirty five bees were fed with each concentration, control bees were fed on 50 % sugar containing the same percentage of the solvent to examine the normal death rate.

Different concentrations of the chemicals were also used by means of micro-pipettes arranged in a holder, and bees were fed individually with the amount of toxic materials (technique used by Eckert 1949) in mailing queen cages by varying the amount fed as well as varying the concentrations of the chemicals. After the bees were fed individually, each was provided with 50 % sugar sirup in a wax cell cup provided to each cage. Bees were then kept in room temperature. Results are shown in Table VII.

Table VII shows that when bees were fed individually on sugar sirup with DDT at the rate of 3-6 mgs. per bee, 21-26.6 % of the bees were killed on the fifth day after feeding. At the rate of 12 mgs. of DDT per bee. 21.7 % were killed on the first day and 60.9 % on the fifth day. All bees fed on 24.30 mgs. died on the fourth day and those fed on 48 mgs. died

TABLE VII

Mortality of bees fed individually with suspension of DDT, benzene hexachloride, and calcium arsenate

TREATMENT	BEES NUMBER	QUANTITY OF INSECTICIDE IN MMG	PERCENTAGE OF MORTALITY IN 1 DAY	2 DAYS	3 DAYS	4 DAYS	5 DAYS
DDT	24	3	4.20	12.60	16.80	16.80	21.00
	30	6	9.90	15.50	19 80	22.10	26.40
	23	12	21.75	39.20	52.20	56.60	60.90
	28	24	71.40	78.50	91.50	100.00	—
	34	42	88.50	100.00	—	—	—
	22	48	100 00	—	—	—	—
Syrup with solvent	28	—	—	3.60	3 60	10.80	10.80
Pure syrup	62	—	—	3 20	6.40	6.40	9.60
Benzene hexachloride(90% gamma)	25	0.025	20.00	28.00	28 00	36.00	40.00
	20	0.050	35.00	40.00	45.00	45.00	50.00
	23	0.100	69.70	74.00	74.00	78.40	78.40
	26	0.250	78.00	82.20	82.20	87.40	87.40
	23	0.400	100.00	—	—	—	—
	28	0.500	100.00	—	—	—	—
Syrup with solvient	28	—	—	3.60	3.60	10 80	10.80
Pure syrup	24	—	—	3.20	6.40	6.40	9.60
Calcium arsenate	28	3	—	—	7.14	10.70	14.30
	36	6	—	—	13.00	24 90	24.90
	23	12	—	17.40	56.30	52.00	52.00
	29	24	—	23.80	51.00	71.40	71.40
	26	36	20 50	68.50	100.00	—	—
	23	42	100 00	—	—	—	—
Syrup with solvent	29	—	—	—	3.40	3.40	6.80
Pure syrup	30	—	—	—	6 60	6.60	9.90

on the first day. In the control where bees were fed on sugar sirup only, 3.2 % died on the first day and 9.6 % died on the fifth day.

Benzene hexachloride 90 % gamma isomer under the same conditions is highly toxic to bees as stomach poison. Feeding bees on 0.05 mgs. caused mortality of 50 % of the experimental bees and 0.1 mg. caused the death of more than 75 % of bees. Feeding bees with 0.5 mg. caused the mortality of all the experimental bees.

The results of feeding bees on calcium arsenate in sugar sirup demonstrate that 6-12 mgs. caused the death of 24-52 % of the bees on the fifth day, 24 mgs. caused the death of over 70 % and 48 mgs. killed all bees on the first day.

From the above data it is shown that calcium arsenate is less toxic as stomach poison to honeybees than benzene hexachloride. Benzene hexachloride is very highly toxic to honeybees as compared with DDT.

Fig. 4 : Battery of micro-pipettes used in feeding bees in individual queen mailing cages.

(3) Laboratory experiments with treated cotton blossoms

Open blossoms of cotton were treated with commercial dusts of :

(1) Cotton dust; (2) DDT at different concentrations; (3) benzene hexachloride (γBHC) as Agrocide 3 and Agrocide 7; (4) calcium arsenate; (5) a mixture of lime + sulphur + calcium arsenate.

A drop of honey was placed in the center of each flower. Worker bees were collected from the feeding hole of the crown board and were kept in cages for about two hours without food to be starved to cease flying. The bees were then placed on the treated cotton blossoms for 5 minutes then were put in cages with feeders of 50 % sugar sirup in an incubator 33°C and 60 % relative humidity. Bees on untreated cotton blossoms were used as control.

Analysis of results

Results of the experiment (Table VIII) show that dusting cotton dust on open blossoms is toxic to honeybees and caused 100 % mortality to bees within 24 hours.

Under the condition of the experiment 1 to 5 % DDT was not toxic to bees, 7.5 % DDT caused 73.08 % kill and 10 % DDT was highly toxic to bees causing 100 % kill in 24 hours.

Results show that benzene hexachloride dust on open cotton blossoms as Agrocide 3 and Agrocide 7 is highly toxic to *Apis mellifica* L.

Calcium arsenate dust killed 74.99 % of bees on the following day of the treatment. The mixture of lime + sulphur + calcium arsenate dust

TABLE VIII

Percentage mortality of adult workers bees the day following treatment of cotton blossoms with cotton dust, DDT, benzene hexachloride, calcium arsenate and lime + sulphur + calcium arsenate

TREATMENT	CONCENTRATIONS	NUMBER OF BEES	PERCENTAGE MORTALITY ON THE FOLLOWING DAY
Cotton dust	10 % DDT + 25 % y BHC gamma isomer 3 % + 40 % sulphur + inert substances 25 %.	23	100
DDT.	2.5 %	27	–
	5.0 %	33	9 09
	7.5 %	24	73.08
	10.0 %	29	100
yBHC.	0.65 % W/W gamma isomer.	21	100
	2 5 % W/W gamma isomer.	27	100
Calcium arsenate		28	74.99
Lime + sulphur + calcium arsenate		24	83.20
Untreated cotton blossoms (control)		29	–

caused 83.2 % kill within 24 hours and all the bees were dead on the third day.

75.9 % of the control bees were still alive on the seventh day of the experiment.

FIELD TESTS ON FORAGING BEES

Methods

Bees which had been working on treated cotton blossoms for a known length of time were caught and caged. Dust treatments were made in small randomised plots. Dust were applied with a rotary hand dust gun. In these experiments cotton dust, 5 and 10 % DDT, benzene hexachloride as Agrocide 3 and as Agrocide 7, calcium arsenate alone and lime + sulphur + calcium arsenate were applied to cotton in bloom. Bees working on untreated cotton blossoms were collected for control tests.

Analysis of results

Results (Table IX) show that under field conditions 100 % of the foraging bees were killed for about one minute with open cotton blossoms treated with cotton dust. 5 % DDT causes 14.3 % mortality as compared to 8.12 % in the case of control bees. 10 % DDT killed 100% of the foraging bees.

TABLE IX

Mortality of adult worker bees on the following day after being collected from various treated cotton blossoms

TREATMENTS	NUMBER OF BEES PER TREATMENT	PERCENTAGE MORTALITY ON THE FOLLOWING DAY
Cotton dust	28	100
Untreated control	19	—
DDT 5 %	21	14.30
DDT 10 %	23	100
Untreated control	24	8.32
γBHC 0.65 %	19	100
γBHC 2.5 %	26	100
Untreated control	27	7.40
Calcium arsenate	22	31.80
Untreated control	23	—
Lime + sulphur + calcium arsenate	23	43.50
Untreated control	29	10.30

Agrocide 3 and Agrocide 7 dusts 0.65 % W/W and 2.5 % W/W gamma isomer are highly toxic to the foraging bees, 100 % of the bees were killed in the following day as compared to 7.4 % of the control bees.

Calcium arsenate is less toxic as contact poison to foraging bees causing only 31.8 % mortality on the first day of the treatment, but on the third day 100 % of the bees were dead. In the control no dead bees were recorded for four days. Dusting of lime + sulphur + calcium arsenate killed 43.5 % the following day and 100 % on the third day. In the control 10.3 % only of the bees were dead.

DISCUSSION

Results of tests conducted in the laboratory show that Cotton dust (10 % DDT + 25 % of BHCγ gamma isomer 3 % + 40 % sulphur + 25 % inert substances) is highly toxic to workers of *Apis mellifica* L.

Commercial preparations caused 100 % kill. Under the same conditions dusting with 10 % DDT killed 100 % of the bees.

In the laboratory dusting 1% DDT had a low effect on honeybees, and there was no significant difference between the death of the experimental and control bees, but dusting with 5-10 % DDT was highly toxic.

Dusting with different commercial preprations of yBHC was highly toxic to honeybees causing 100 % mortality on the first day of the application.

Residues on glass surfaces sprayed with different concentrations of DDT showed that 0.1 % had insignifiant effect on bees, while 0.5 % sprays greatly increased mortality, and 1 % killed most of bees in 10 to 20 minutes. Residues of yBHC sprays were highly toxic to bees. Concentrations of 0.0032 and 0.0065 % yBHC killed the bees in 10 minutes.

Stomach poison action was determined by feeding bees individually in the laboratory. Results show that yBHC is more toxic than DDT. Calcium arsenate under the experimental conditions is less toxic than benzene hexachloride and more so than DDT.

Field tests with cotton dust now in use against the cotton leaf-worm *Prodenia litura* F. in Egypt indicates that 100 % of honeybees visiting dusted flowers are killed.

Dusting cotton fields with different concentrations of DDT during the blooming period shows that applications of 5 % DDT dust affected few foraging bees, but applications of 10 % proved to be dangerous.

Results of dusting commercial preprations of benzene hexachloride with different concentrations of y gamma isomer caused serious loss to bees visiting cotton blossoms. Agrocide 7 with y gamma isomer W/W 2.5 % and Agrocide 3 with y gamma isomer W/W 0.65 % when applied to cotton plants in bloom killed all bees visiting treated flowers.

It is evident that there is a serious risk to bees from benzene hexachloride dust when applied to blooming plants.

Results of field experiments with calcium arsenate and lime + sulphur + calcium arsenate confirm those obtained in the laboratory and show that they are lethal to bees as stomach poisons, when applied on open cotton blossoms, but are less toxic as contact poisons to the foraging bees.

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Bruchidius alfierii Pic, a biologic race of *Bruchidius trifolii* Motsch.

[Coleoptera : Bruchidae]

(with 2 Tables)

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CONTENTS

Introduction. — Nomenclature. — Distribution in Egypt. — Host plants. — Biology. — Material and technique. — Preliminary work. — Breeding experiments. — Synonymy. — Discussion and conclusions. — Summary. — Acknowledgments. — References.

INTRODUCTION

The seeds of the Egyptian clover (*Trifolium alexandrinum* L.) are usually infested by hitherto two beetles, *Bruchidius trifolii* Motsch. and *Bruchidius alfierii* Pic. The beetles affect the viability of the seeds to a large extent raising the cost of sowing. Bearing in mind that about fifty thousands tons of seeds are sown anually and that the value of each ton may reach 250 - 300 Egyptian pounds, it is obvious that the damage done by these pests is very important.

The informations about the biology of these pests are very limited. Only speculations and assumptions have been put forward about the biology and control of *B. trifolli* (Willcocks, Hassan). Therefore the object of this work has been to clarify several points concerning the biology of *B. trifolii*. But, for reasons to be mentioned later, attention has also been directed to *B. alfierii*, and the relations between the apparently two species has been found out. In fact the main work in this paper is to show this relation with enough evidence to prove that *B. alfierii* Pic is a biologic race of *B. trifolii* Motsch.

NOMENCLATURE

Bruchus trifolii Motsch. was described in 1873. This insect infests clover seeds in Egypt, Carniola (Jugoslavia) and Germany. Schilsky created the genus *Bruchidius* which has a regular prothorax, while the genus *Bruchus*

is characterized by the presence of a prothoracic kink. In 1922, a new species infesting clover seed in Egypt was collected by Alfieri and described by Pic under the name of *Bruchus* (*Bruchidius*) *alfierii*. Both species, *alfierii* and *trifolii*, differ from each other in that the former has reddish legs and antennae whereas the latter has blackish appendages.

DISTRIBUTION IN EGYPT

In 1943, the following data were supplied to me by Rizk Attia for *B. trifolii* : Kafr El-Sheikh, April 1935, on fenugreek (*Trigonella foenum graecum*) and horse-beans (*Vicia faba*), Marg, May 1935 ; Gimmaiza, June 1935 (by sweeping) ; Ducki (Giza), April 15th, 1935 ; Gimmaiza, April 20th (by sweeping) ; and Itay El-Baroud, in store. In 1952, I was informed by El-Kifl that he found *Bruchidius trifolli* among soil Coleoptera to a depth of 10 inches, but prevailing in the 3 inches upper surface. It occurred in the soil only in winter, especially during December and January. Willcocks reported the presence of *Bruchidius trifolii* in winter among other insects in leaf-galls caused by thrips on « sunt » trees (*Acacia arabica* Willd.). He concluded that the insect was no doubt hibernating.

HOST PLANTS

The main host of the insect is « berseem » seeds (the Egyptian clover) which grows in Egypt, Cyrenaica (Muschler), and to some extent in the United States (Robbins). In Egypt, seeds are sown from September up to the end of November. Flowering starts from March and continues throughout April and May according to the locality and the time of the last cut preceeding flowering for seeds. The one-cutting berseem « Fahl » is harvested in Upper-Egypt early in March and April, whereas the several-cutting berseem « Miskawi » is harveted in May and June.

It is important to mention that fourteen other species of *Trifolium* are recorded in Egypt by Muschler, mostly as weeds and wild plants which might be secondary hosts.

BIOLOGY

Willcocks assumed that oviposition occurs on unripe seed capsules or ovaries in the field. Adults aestivate in seeds or under suitable shelter, issue in swarms when sowing, and hibernate until March when seen on flowers of wheat ready for infesting the new crop. Willcocks questioned whether the insect has one or several broods in spring and early summer, and whether successful re-infestation of the seeds takes place in stores. Although Willcocks showed that Bruchids which emerge from harvested

seeds in sacks may lay eggs on ripe seeds, yet he did not believe that development can take place.

MATERIAL AND TECHNIQUE

Source of infested seeds

Infested seeds were obtained from the store of the Faculty of Agriculture at Giza. Some samples were obtained from Assiut (Upper-Egypt) and Beltag (Lower-Egypt). Seeds or mature heads from standing crop were kept in small linen bags or in jars, and were obtained from heads by using simple mechanical means such as hand rubbing.

Collecting adults

Adults to experiment with were obtained from those self-emerging from stock infested seeds or by sweeping from standing crops in the field. Forced emergence of adults from seeds was simply done by moistening the seeds on a filter paper or a thin layer of cotton wool in a covered Petri dish. Later, it was found that sowing infested seeds in a small pot full of wet soil and covered with muslin gave the best rate of emerging adults. For sweeping, an ordinary muslin (circa 25 cms. diameter) was used ; certain number of « sweepings » were done successively while walking forward in the field and the number of insects obtained was used for rough comparison of the insect distribution.

Specimen glass tubes (1 cm. diameter $\times$ 5 cms. length) stoppered with a piece of muslin cloth held tightly with a small rubber band, were used for breeding.

Food

Berseem seeds were the only food used for breeding the insects. In few cases in hot weather, a moistened piece of filter paper (2 cm^2) was inserted in the breeding tubes. It was observed that the adults visited the moistened paper, and that this increased their longivity.

During the season 1943-44, three varieties of berseem (Miskawi, Fahl and Baaly) were sown at the Faculty farm, each in an area of 8 $\times$ 2 metres. The clover was not cut in order to have flowers at an early date in the season for studying some biological aspects. In case of Fahl and Baaly, flowering started at the begining of March, and mature seeds seeds were obtained at the end of April.

This biological work was carried out throughout three seasons, viz. 1943-44, 1944-45 and 1952-53, under ordinary laboratory conditions.

PRELIMINARY WORK

Infestation of old seeds in store

Several samples of seeds (Fahd and Baaly) were examined as from January 1943 and were found infested, those from Upper-Egypt very slightly while those from the north in some cases very heavily, the percentage of infestation being as high as 64. Adults of *B. trifolii,* both alive and dead, were found among and within the seeds, but only few dead adults of *B. alfierii* were found mostly outside the seeds. Seeds containing adult Bruchids were easily recognized by the presence of a round black spot which was easily distinguished from a naturally irregular greenish spot found opposite the hilum of the seed.

Although some infested seeds had four white eggs on the testa and more than one larval hole, only one adult was found in a seed. Few eggless seeds had a small scar which was of the size of a larval hole, surrounded with yellowish and brown irregular area. This indicated the site of infestation of the green seed in the field.

It was obvious that the presence of two types of larval infestation and the presence of adults in the dry seeds infested with eggs, were an indication that there had been re-infestation on mature dry seeds in store. But surprisingly, during this period (January-June) the emerging adults from stored seeds did not copulate or re-infest the seeds ; they were all *B. trifolii* individuals which died gradually when kept in specimen tubes and sound seeds. It was also found that a great number of adults « hibernating » in the unsown seeds failed to emerge and gradually die. In 1943, the percentage of alive adults from total number of insects found in seeds was 96 in January, 33 in March, and 24 in April. This percentage decreased gradully from January, and at the end of June all insects were found dead.

This fact indicates that « hibernating » adults in the unsown seeds could not survive or reproduce in store. Not until further experiments on a new crop, the absence of alive adults of *B. alfierii* during this period could be explained.

Infestation of the new crop (June 1943 - May 1944)

A heap of unthreshed crop was found on June 12th to be heavily infested with *B. alfierii* which flew about actively. Hollow seeds in the heads, eggs on seed capsules, larval and pupal stages, and only few adults of *B. trifolii* within the seeds were all found in infested seeds. During August, all stages of the insect were found in the infested seeds, the majority of emerging adults being *B. alfierii* which moved actively, copulated and laid eggs on the seed. Few dead adults *B. alfierii* were found dead among the seeds and few alive *B. trifolii* were found within the infested seeds.

Breeding B. alfierii

Twenty *B. alfierii* newly emerged on August 10th were kept with forty sound seeds. Copulation occurred immediately, lasting for few minutes, and eggs were deposited after four hours. Oviposition (up to seven eggs per seed) continued for few days, and the adults died gradually after a maximum longevity of ten days. Development took place and, in a month time one *B. alfierii* emerged. Then, unexpectedly, one *B. trifolii* emerged. The remaining seeds contained *B. trifolii* which, after emergence, did not copulate or lay eggs, but died gradually behaving similiar to *trifolii* individuals emerging in store after January.

Re-examination of infested seeds in store (October - May 1944)

During this period the alive adults belonged only to *B. trifolii* which did not re-infest the seeds, but remained within the seeds for several months or emerged. The longivity of emerging adults lasted up to three months when kept in muslin bags or specimen tubes. The number of insects naturally emerging diminished gradually, and emergence ceased at the end of April, but forced emergence continued for a month later. This indicated that some adults were weak enough to push through the hard exit of a dry seed, but strong enough to emerge from a moistened soft seed.

During this period the reproductive system of the female adults obtained in store were examined. It was possible to see the ovarioles, but eggs were absent.

Sweeping during spring and early summer

Sweeping indicated that *B. trifolii* was present on the following plants when in blooms : berseem, wheat, barley, horse-beans, lentils, fenugreek, *Lathyrus sativus* and *Reseda odorata,* but was not on either young or seeding wheat and barley. It was also not found in some flowering plants as phlox snag dragon (*Antirrhinum* spec.) and *Brassica alba.*

The insect was more attracted to berseem flowers which appeared in March (see Table I). It could not be found on berseem when not in bloom. Before berseem reaches maturity, only *B. trifolli* was collected, but during June, on a nearly mature crop of berseem, both *B. trifolii* and *B. alfierii* were collected along with some intermediate individuals (with dark-brown appendages or with half-dark-brown and half-black ones).

Swept *B. trifolii* was regularly kept in specimen tubes with sound seeds. Insects swept before the last days of March died gradually without ovipositing eggs, whereas those swept later laid eggs. Eggs were deposited

on the 30th of March 1944. In the field, however, eggs were first seen on flowers on the 28th. Infestation of sound seeds by swept *B. trifolii* was even possible during April, and offspring of both *B. trifolii* and *B. alfierii* were produced, the latter being the majority.

Male and female adults

Gorham recorded some superficial sexual characters in Bruchidae. However, it is possible to differentiate the sexes even with the naked eye. The male adult has a relatively longer antennae for their terminal joints are longer than those of the female, which are stouter and rather club-like.

TABLE I

Berseem seed-beetles swept (100 *times*) *from berseem*

DATE	LOCALITY	STAGES OF CLOVER GROWTH	NUMBER OF BEETLES AND SPECIES
4. III. 1944	Giza	one flower	1 *B. trifolii*
16. „	„	majority flowering	45 „
20. „	„	few flowers	2 „
21. „	„	majority flowering	20 „
26. „	„	full flowering	several *B. trifolii*
28. „	„	half flowering	8 „
21. IV. 1944	„	majority flowering	150 *B. trifolii*
22. „	„	nearly ripe	150 *B. trifolii* + 1 *B. alfierii*
31. „	„	majority flowering	200 *B. trifolii*
15. V. 1944	„	full flowering	50 *B. trifolii*
16. VI. 1944	Beltag	nearly ripe	numerous *B. trifolii* and *B. alfierii*, and few intermediate individuals.
11. III. 1945	Giza	full flowering	40 *B. trifolii*
13. „	Moshtohor	„	74 „
25. „	Giza	„	20 „
27. „	Moshtohor	„	180 „
29. „	Giza	„	75 „
2. IV. 1945	Moshtohor	„	580 „
3. „	„	„	446 „
9. „	„	„	500 „
17. „	„	„	600 „
24. „	„	„	320 „
8. V. 1945	„	„	400 „
13. „	„	„	50 „

BREEDING EXPERIMENTS

The foregowing results show that a special relation existed between *B. trifolii* and *B. alfierii*. It is also clear that *B. trifolii* adults obtained from seeds in store were sexually immature and incapable of breeding. Breeding is only possible in a new season, by infesting sound seeds by sexually mature *B. trifolii* swept from the field or by using the first generation produced from mature *B. trifolii* parents in an early new crop.

Breeding from adult B. trifolii swept from clover

(a) Although swept insects laid eggs on sound seeds at the end of March, successful infestation was only obtained on May 2nd. 1944. On June 4th, thus after one month, both *B. alfierii* (reddish-brown form) and *B. trifolii* (blakish form) started emergence, the former being the majority.

(b) In 1945 swept *B. trifolii* successfully infested seeds in April 4th. First generation started emergence after twenty-five days and produced almost more *B. alfierii* than *B. trifolii.*

(c) *B. alfierii* issued from first generation bred in seeds on May 7th gave rise to the second generation which started in a month time and produced *B. alfierii, B. trifolii,* and very few intermediate individuals.

(d) Twenty pairs of *B. alfierii* originating from the second generation were separated on June 6th. They produced the third generation with all types (*B. alfierii, B. trifolii,* and intermediate individuals).

Breeding of B. alfierii

B. trifolii individuals produced in store during summer and autumn did not reproduce as they were sexually immature.

(a) From an ordinary crop (Miskawi) in June 1944 (Table II, No. 9) parents *B. alfierii* produced reddish-brown, blackish and intermediate types in the second generation. *B. alfierii* of the second generation (Table II, Nos. 12, 13, and 14) further produced reddish-brown and blackish individuals in third generation.

(b) In 1952, from a late crop in July, eleven pairs of *B. alfierii* emerging (Table II, Nos. 18-28) produced in second generation ten *B. alfierii,* two-hundred and thirteen *B. trifolii,* and two intermediate individuals. A further generation from second generation (Table II, No. 29) produced only *B. trifolii* in third generation.

(c) Breeding took place from *B. alfierii* individuals in store between May-September. In the offsprings the number of *B. alfierii* decreased as autumn approached while that of *B. trifolii* increased. Intermediate individuals were very scarce. From parents in July (see (b) above) only 4.4 % of offspring were *B. alfierii,* while from parents in May, about 80 % were *B. alfierii,* from parents in August and September only about 2 % were again *B. alfierii.*

Cross-breeding

(a) First attempt was successful by pairing a male *B. trifolii* swept from a clover field to a female *B. alfierii* emerging from an early crop (Table II, No. 11). Development was successful, and both *B. trifolii* and

B. alfierii were obtained. The *B. trifolii* offsprings failed to reproduce, but further reproduction of *B. alfierii* was successful.

TABLE II

Breeding of clover seed-beetles in 1943, 1944 and 1952.

NUMBER	DATE	PARENTS	FIRST GENERATION			NUMBER OF EGGS DEPOSITED	SHORTEST PERIOD FOR REACHING ADULT STAGE IN DAYS
			B. alfierii	*B. trifolii*	intermediates		
1	12. VIII. 1943	19 *B. alfierii*	1	39			27
2	20. V. 1944	male and female *B. alfierii*	1			9	27
3	25. „	10 *B. alfierii*	2				26
4	28. „	male and female *B. alfierii*	1			37	24
5	29. „	male *B. alfierii* and female intermediate	3	2		13	27
6	3. VI. 1944	male and female *B. alfierii*		1		26	
7	7. „	male and female intermediates		13			
8	7. „	males *B. alfierii* and intermediate and female *B. alfierii*		13		59	34
9	9. „	male and female *B. alfierii*	9	11	4	69	20
10	13. „	3 males and 3 females *B. alfierii*	10	3			
11	22. „	male *B. trifolii* (swept) and female *B. alfierii*	6	10			30
12	30. „	male and female *B. alfierii* (first generation in No. 9)		14			
13	30. „	„	1	7			35
14	1. VII. 1944	„	1	15			
15	6. IX. 1944	male and female *B. alfierii*		21			
16	7. „	„	1	19			
17	22. VII. 1952	24 *B. alfierii*	5	35			
18	„	male and female *B. alfierii*	1	18			
19	„	„		21	1		
20	„	„	1	9	1		
21	„	„	4	6			
22	„	„	1	18			
23	„	„		22			
24	„	„		18			
25	„	„		31			
26	„	„	2	30			
27	„	„		19			
28	„	„	1	21			
29	24. VIII. 1952	male *B. alfierii* (first generation in 20) and female *B. trifolii* (first generation in 19)		9			

(b) In 1945, five pairs (*B. alfierii* emerging × *B. trifolii* swept were bred during the second half of May. Development took place, the majority of the first generation being *B. alfierii*. The *B. alfierii* offspring (eight pairs taken on the 21st of June) bred successfully, producing both reddish-brown and blackish individuals.

(c) Attempts to cross females of *B. trifolii* emerging from seeds in store with males of *B. alfierii* were unsuccessful because *B. trifolii* individuals were sexually immature.

(d) It is to be noted that crossing sexually mature females of *B. trifolii* swept together with males of *B. alfierii* was not attempted because the females swept might have already copulated with a male *B. trifolii* in the field. But on September 24th 1952, a case occurred (Table II, No. 29) when a female *B. trifolii* newly emerging copulated with a male *B. alfierii* producing nine *B. trifolii* individuals.

Other breedings

(a) On May 3rd. 1945 a case occurred when a male and a female *B. trifolii* emerging in store copulated and produced a generation.

(b) Intermediate individuals emerging in store reproduced successfully with one another (Table II, No. 7) or with *B. alfierii* ones (Table II, Nos. 5 and 8).

This shows clearly that some individuals of *B. trifolii* (blackish form) which emerge from seeds in store during summer behave as reddish-brown forms and are sexually mature.

SYNONYMY

These findings led the author to believe that *B. trifolii* and *B. alfierii* are most probably but one and same species having two inter-related forms, a « reddish-brown » which reproduces in store during summer giving a sexually immature « blackish form » at the end of the season. These « blackish form » individuals would continue to be sexually immature in store, but in the field, after visiting the flowers, they would become sexually mature. This indicates that feeding is essential for the development of eggs in the ovaries of this form.

DISCUSSION AND CONCLUSIONS

Production of *Bruchidius trifolii* individuals from *Bruchidius alfierii* parents and vice-versa, successful crossing between the two forms followed by further successful inter-breeding of « crosses » and presence of intermediate forms of individuals, are collective proofs that both *B. alfierii* and *B. trifolii* are but one species. Colour differences of appendages are more or less due to a kind of polymorphism.

It appears more convenient to divide the individuals of the Egyptian clover seed-beetle into two forms :

(a) Sexually mature form which is found in stored seed from the new crop until October. The insects reach the adult stage in about a month (20-35 days), and emerge from the seeds for mating and are short-lived. In this form the majority of individuals have reddish-brown appendages; some individuals may have black appendages or intermediate between reddish-brown and black ones.

(b) Sexually immature form in store, in which the individuals reach the adult stage in the seed. They have black appendages, and continue to be sexually immature in store. They are long-lived and must visit the flowers in the field before getting sexually mature for field infestation. They are produced either from their type after getting-sexually mature or as offspring of parents from the sexually mature form. Their number increases gradually in successive generations of the sexually mature form, as autumn approaches.

SUMMARY

Some biological aspects of *Bruchidius trifolii* Motsch. and *B. alfierii* Pic were studied. The « two species » interbreeds successfully and breeding experiments proved that « both species » are synonymous.

The species reproduces in store in a special manner, producing sexually mature individuals and sexually immature ones, the former having reddish-brown appendages in nearly all individuals, but the latter having blackish appendages. The first form mate directly after emregence and is also short-lived, while the latter continues to be sexually immature until it migrates to the field in order to feed and sexually become mature and thus capable of infesting seed in the field or in store.

ACKNOWLEDGMENTS

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Gerris paludum palmonii nov. subspec., ein neue Gerridenrasse aus dem vorderem Orient

[Hemiptera-Heteroptera]

(mit 13 Abbildungen)

von Eduard Wagner, Hamburg

Schwarzbraun, sehr fein und kurz hell behaart. Schlank. Kopf (Fig. 1) vor den Augen schmal, nach vorn zugespitzt; Augen gross, gewœlbt, glänzend. Scheitel beim ♂ 1,15×, beim ♀ 1,2× so breit wie das Auge; am Hinterrand eine gewinkelte, braune Querlinie. Kopf samt Augen 1,3-1,4× so breit wie der vordere Teil des Pronotum; die Augen überragen die Vorderecken des Pronotum nach der Seite mit etwa der Hälfte ihrer Breite. Fühler lang und schlank, das 1. Glied sehr lang, 2,6-2,7× so lang wie das 2.; das 3. Glied ist das kürzeste und nur 0,8-0,9× so lang wie das 2.; das 4. Glied 1,25-1,30× so lang wie das 3. Schnabel kurz.

Pronotum land und schmal; vorderer Teil mit gelblicher Mittellinie; hinterer Teil mit grossem, braunem Mittelfleck, der bisweilen fehlt oder undeutlich ist. Dicht unter dem Seitenrande eine gelbliche Längsline, die im vorderen Teile fehlt. Halbdecken bald verkürzt und bis zum Ende des 5. Abdominalsegmentes reichend (f. brach.), bald voll entwickelt und das Hinterleibsende erreichend (f. makr.); braun bis schwarzbraun, Adern schwarz. Grund der Halbdecken bisweilen heller. Rücken mit hellen Randern, bisweilen auch mit heller Mittellinie. Hinterecken des 7. Abdominalsegments in eine lange, etwas geschweifte Spitze ausgezogen (Fig. 2+3), die das Hinterleibsende überragt. Unterseite silberglänzend. Beine schwarzbraun bis braun.

Genitalsegmente des ♂ (Fig. 4) schlanker, das 8. Segment vor der Oeffnung deutlich eingeschnürt. 9. Segment distal breit gerundet (Fig. 10), fein und abstehend behaart. Analkonus (10. Segment) von oben gesehen (Fig. 6) schlank, distal verjüngt; seitlich gesehen (Fig. 8) distal gerundet und kaum eingekerbt. Penis birnfœrmig, stark glänzend und pigmentiert. Parameren (Fig. 13) schlank und verhältnismässig lang, distal verjüngt, fast viereckig.

Länge: ♂ = 12-13mm., ♀ = 13,5-15,5mm.

Die neue Subspecies ist etwas kleiner und schlanker als die Nominatrasse, vor allem aber heller gefärbt. Bei *G. paludum paludum* F. ist der hintere Teil

des Pronotum stets einfarbig schwarzbraun, ebenso die Halbdecken und die Beine. Der Kopf ist hier nur 1,20-1,25× so breit wie der vordere Teil des Pronotum (Fig. 1), der deutlich breiter erscheint; die Augen überragen daher die Vorderecken des Pronotum kaum nach der Seite. Die Spitzen des 7. Hinterleibssegments sind kräftiger und gerader. Ihre Form schwankt jedoch erheblich. Dagegen scheint die Form der Genitalsegmente konstant zu sein. Die Genitalkapsel ist bei *G. paludum paludum* F. (Fig. 2) erheblich breiter,

Fig. 1-3. — *Gerris paludum* F.: obere Reihe = *G. paludum palmonii* nov. subspec.; untere Reihe = *G. paludum paludum* F.
Fig. 1 = Kopf und vorderer Teil des Pronotum von oben (11×), ♂; Fig. 2 = Hinterleibsende des ♂ (22.5×); Fig. 3 = dasselbe vom ♀.

viel weniger deutlich eingeschnürt (Fig. 5); das 9. Segment ist distal fast gerade abgestutzt (Fig. 11); der Analkonus (Fig. 7) breiter und distal breiter gerundet, seitlich gesehen (Fig. 9) deutlich eingekerbt und viel spitzer. Die Parameren (Fig. 12) sind viel kürzer und breiter, vor allem proximal sehr breit.

Ich untersuchte 4 ♂♂ und 5 ♀♀ aus Palästina: Dagania am See Genezareth 1938 (J. Palmóni leg.) und SDE Nachum, Beth Shan 5. + 10. 52 (Dr. Fischer leg.).

Ich erlaube mir, die neue Subspecies nach dem ersten Sammler der Form, Herrn J. P a l m o n i zu benennen. Offenbar handelt es sich hier um eine ostmediterrane Rasse des weit verbreiteten *G. paludum* F., die vielleicht

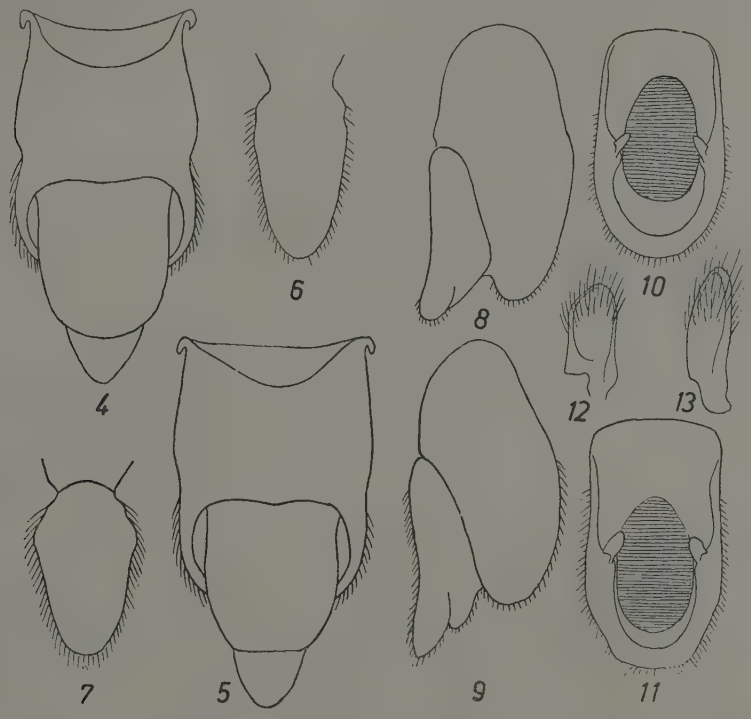


Fig. 4-13. — Genitalien des Männchens: Fig. 4, 6, 8, 10 und 13 = *G. paludum palmonii* nov. subspec.; Fig. 5, 7, 9, 11 und 12 = *G. paludum paludum* F. Fig. 4+5 = Genitalkapsel von unten (31,5×); Fig. 6+7 = Analkonus (10. Segment) von oben (31,5×); Fig. 8+9 = 9.+10. Segment seitlich (31,5×); Fig. 10+11 = 9. Segment von oben (31,5×); in der Mitte der Penis (schraffiert); Fig. 12+13 = Paramere, seitlich (84×).

auch in den Nachbarländern vorkommen dürfte. Auch bei der ostasiatischen var. *remigator* Horv. dürfte es sich um eine geographische Rasse handeln.

Holotypus und Allotypoid und Paratypoide in meiner Sammlung. Paratypoide auch in der Sammlung der Fish Experimental Station Nachum, Israel.

Orius laevigatus inaequalis E. Wagner aus Aegypten

[Hemiptera-Heteroptera]

von Eduard Wagner, Hamburg

Bei der Beschreibung der obigen Subspecies (1952) lagen mir nur wenige Tiere vor, so dass ich damals keine genaue Beschreibung geben konnte. Inzwischen sandte mir Herr Prof. Priesner, Kairo sein Material von *Orius* Dabei konnte isch feststellen, dass alle Stücke von *O. laevigatus* Fieb. zu der obigen Subspecies gehœren. *O. laevigatus laevigatus* Fieb. fand sich nicht unter dem Material und scheint in Aegypten garnicht vorzukommen. Es handelt sich demnach bei *O. laevigatus inaequalis* m. um eine geographische Rasse. Eine eingehende Beschreibung mœge hier folgen :

Gestalt lang oval, das ♂ 2,9×, das ♀ 2,8-2,85× so lang wie das Pronotum breit ist. Glänzend, fein hell behaart.

Kopf kurz, schwarz, Scheitel beim ♂ 2,0×, beim ♀ 2,2× so breit wie das etwas flachere Auge. Fühler hellgelb, beim ♂ distal etwas dunkler und stark verdickt; 1. Glied beim ♂ 1,17×, beim ♀ 1,0× so lang wie das Auge breit ist, schwarz; 2. Glied deutlich länger, beim ♂ 1,7×, beim ♀ 1,3× so lang wie der Scheitel breit ist und beim ♂ 0,84×, beim ♀ 0,67× so lang wie der Kopf breit ist; 3. Glied deutlich länger als das 4. und 0,60-0,65× so lang wie das 2. Glied.

Pronotum schwarz, glänzend, an den Ecken mit langen Borsten, hintere Fläche zerstreut punktiert. Scutellum querüber eingedrückt, vorderer Teil glatt, hinterer Teil querrunzelig.

Halbdecken fast glatt, gelbbraun, Cuneus und hinterer Teil des Corium oft dunkelbraun, äusserste Spitze des Cuneus oft hell. Membran im hinteren Teile dunkel rauchbraun, im vorderen hell, fast weiss, beide Teile durch eine gerade, querlaufende Linie getrennt. Unterseite schwarz. Beine hellgelb, alle Schenkel mit Ausnahme der Spitze schwarz, die Hinterschienen graubraun bis schwarz, in der Regel auch die Mittelschienen (♀). Tarsen schwarz.

Genitalgriffel das ♂ klein, der Zapfen lang und schmal, kaum verjüngt, distal etwas nach innen gebogen, ohne Zahn, Geissel mit 2 Armen, die fast gerade sind, der äussere ist aber nur etwa halb so lang wie der innere und der innere etwas kürzer als der Aussenrand des Zapfens.

Lange : ♂ = 1,9-2,5mm, ♀ = 2,2-2,5mm.

Die subspec. *inaequalis* m. unterscheidet sich von der Nominatrasse durch längere Gestalt, etwas breiteren Scheitel, längere Fühler, vor allem längeres 2. Glied, kräftiger gefärbte Schienen und den Bau des Genitalgriffels, dessen Geissel bei *O. laevigatus laevigatus* Fieb. zwei gleichlange Arme hat.

Ich untersuchte weitere 1 ♂ und 27 ♀ aus Aegypten : Wadi el Tih 20.+24. 2.39, 1 ♂ , 18 ♀ ♀ ; Suez Road 1.3.36, 7 ♀ ♀ ; Montaza 1.3.39, 1 ♀ ; Matrouh 1 ♀ , sämtlich H. Priesner leg.

Die Fulgoroidea der Omer-Cooper-Expedition in die Lybische Wueste

[Hemiptera - Homoptera]

(mit 41 Abbildungen)

von W. Wagner, Hamburg.

Herrn Prof. W. E. China vom Britischen Museum verdanke ich die Mœglichkeit, die Fulgoroidea bearbeiten zu kœnnen, die Herr Dr. Omer-Cooper in der Zeit vom 18.4.-9.9.1935 in den Oasen der Siwa-Depression in der Lybischen Wüste gesammelt hat. Mir lagen 543 Exemplare vor, von denen 541 determiniert wurden. In der Ausbeute konnten die folgenden Arten festgestellt werden.

Mœglich wurde die Bearbeitung erst durch die freundliche Unterstützung von Herrn Prof. China vom Britischen Museum in London, Dr. M. Beier, Naturhistorischen Museum in Wien, Dr. J.V. Stehlik vom Mährischen Museum in Brno und Dr. E. Séguy vom Museum National d'Histoire Naturelle in Paris, die mir Typen und anderes wichtige Material zur vergleichenden Untersuchung zur Verfügung stellten. Diesen Herren mœchte ich auch an dieser Stelle meinen aufrichtigen Dank für ihre bereitwillige Hilfe aussprechen.

CIXIIDAE

Oliarus suezensis Mats. 1910

1910 *Oliarus suezensis* Matsumura, Journ. Coll. Sci. Tokyo, 27:7.
1936 *Oliarus suezensis* Metcalf, Gen. Cat. Hem. 4 (2): 104.

Da Matsumura nur eine kurze Beschreibung der Genitalien bringt, ergänze ich sie hier durch eine ausführlichere und durch Zeichnungen.

♂.— Genitalsegment fast symmetrisch, die rechte Seitenwand etwas kürzer und mit flacherem Bogen zum Hinterrand abgerundet als die linke, ohne Dornen und Fortsätze (Abb. 1). Afterrœhre von oben gesehen breit oval, hinten flach ausgerandet ohne Dornen und Fortsätze am Ende. Unterrand von hinten gesehen fast gerade, nur ganz schwach ausgebogen und mit schwach vorgewœlbtem Mittelteil (Abb. 2). Griffel am Ende hakenfœrmig gebogen. Der Hinterrand dieses Endteiles parabolisch; Stiel des Griffels vor dem Endteil halsartig eingeschnürt, vor der Einschnürung besonders nach unten stark verbreitert und mit scharfer Kante (Abb. 3 u. 4). Der am Grunde

des Penis entspringende grosse Dorn, der das Ende des Penis umfasst, stark blattartig verbreitert, rechtwinklig gebogen und in einen blattartigen, stark zugespitzten und gebogenen Endteil auslaufend (a in Abb. 5 u. 6). Am Ende des Penisschaftes 3 gekrümmte Dornen: an der Oberseite ein längerer (b in Abb. 5 u. 6) und ein etwas kürzerer, der sich um den Endteil des Penis herumschmiegt (c in. Abb. 5 u. 6), auf der Unterseite ein kurzer (d in Abb. 5 u. 6). Endteil des Penis mit einem rechtwinklig abgebogenen, verhältnismässig langen Dorn (e).

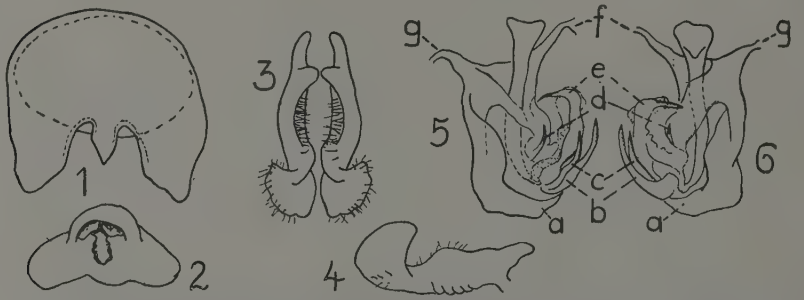


Abb. 1-6. — *Oliarus suezensis* Mats. (El-Arig, Omer-Cooper leg): 1. Genitalsegment von unten; 2. Analsegment von hinten; 3. Griffel von oben; 4. Ders. seitlich; 5. Penis von unten; 6. Ders. von oben.

♀. — Genitalsegment mit breitovaler, flach schüsselförmiger dicht behaarter Hinterfläche. Analsegment fast rechteckig, wenig länger als breit, mit etwas vorgezogenen Hinterecken, oberseits flach, unterseits schwach gewölbt. Legescheide kurz, etwa 3/4 so lang wie die Höhe der Hinterfläche des Genitalsegments.

Siwa 32 ♂♂ u. 28 ♀♀, 3.5. bis 9.9; Maragi 6 ♂♂ u. 5 ♀♀, 24.6 bis 26.8.; Khamissa 17 ♂♂ u. 15 ♀♀, 4.5. bis 28.8.; Koreishid 14 ♂♂ u. 5 ♀♀, 30.6.; Baharein 126 ♂♂ u. 29 ♀♀, 9. bis 17.6.; El Arig 2 ♂♂, 7. bis 8.6; Tenterad 1 ♂ u. 2 ♀♀, 26.7. : Sitra 1 ♂ u. 1 ♀, 15.6. ; Ilrhabit Uncorde 1 ♂ u. 3 ♀♀, 18.5. ; Jagub 1 ♀, 18.-19.8. ; Zeitoun 1 ♀, 2.9. ; Tutuatee 1 ♀, 26.6.

Pseudoliarus fuscofasciatus Mel. 1902

1902 *Oliarus fuscofasciatus* Melichar, Ann. Mus. St. Petersburg 7: 88.
1927 *Pseudoliarus fuscofasciatus* Haupt, Inst. Agric. Nat. Hist. Bull. 8: 7 u. Tf. 1.
1936 *Pseudoliarus fuscofasciatus* Metcalf, Gen. Cat. Hem. IV (2): 131.

Eine ergänzende Beschreibung gab Haupt 1927. Der freundlichen Bereitwilligkeit von Herrn Dr. Stehlik verdanke ich die Möglichkeit, auch die Typen Melichars untersuchen zu können. Ausserlich stimmen die

lybischen Tiere mit den Typen überein. Aber bei der Untersuchung der männlichchen Genitalien ergaben sich Unterschiede, die wahrcheinlich bedingt sind durch eine geographische Variabilität. Da die Stücke aus der Siwa-Depression übereinstimmend die gleichen Abweichungen von der untersuchten männlichen Type zeigen, erscheint es berechtigt, sie als geographische Subspecies zu benennen. Ein mir vorliegendes einzelnes ♂ aus Palästina weicht in anderer Weise von der Type ab, so dass anzunehmen ist, dass es sich hier um eine dritte geographische Subspecies handelt. Ich benenne die Subspecies aus Lybien.

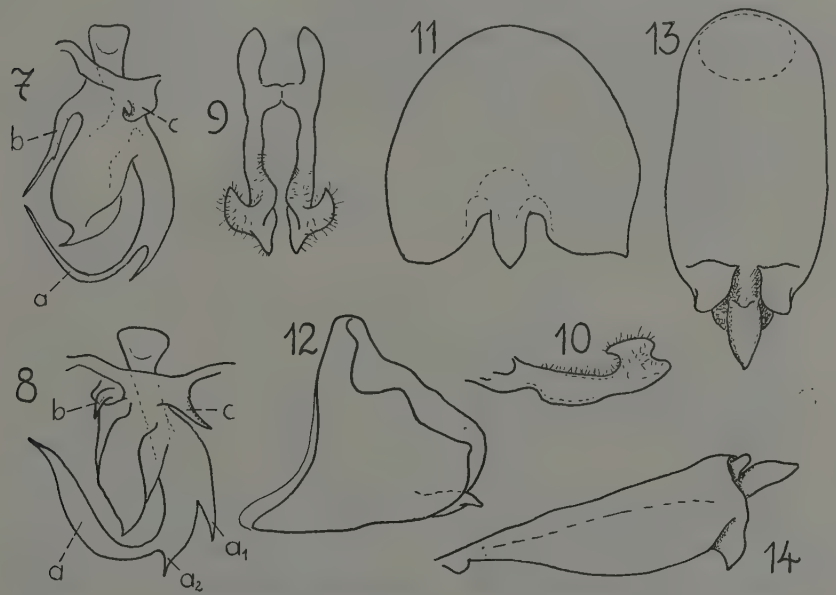


Abb. 7. — *Pseudoliarus fuscofasciatus fuscofasciatus* Mel., Type: Penis von oben.

Abb. 8-14. — *Pseudoliarus fuscofasciatus aegyptiacus* n. ssp.: 8. Holotype, Penis von oben; 9. Holotype, Griffel von oben; 10. Holotype, Griffel seitlich; 11. Holotype, Genitalsegment von unten; 12. Holotype, Dass. seitlich; 13. Paratypoid (Baharein), Analsegment von unten; 14. Paratypoid (Siwa), Analsegment seitlich.

Pseudoliarus fuscofasciatus aegyptiacus n. ssp.

Genitalsegment unsymmetrisch. Der Hinterrand der rechten Seite gleichmässig abgerundet, der Hinterrand der linken Seite in eine Ecke ausgezogen. Der Oberrand zwischen dieser Ecke und dem Hnterrand einmal breit und flach und davor kürzer und tiefer ausgerandet (Abb. 11 u. 12). Griffel am Ende hakenförmig nach oben umgebogen, das Ende nach hinten in einen Lappen verlängert (Abb. 9 u. 10). Analsegment 1 1/2 mal so lang

wie breit, lang oval mit fast parallelen Seiten. Unter den Hinterecken jederseits spitze dreieckige, nach unten weisende Ecke (Abb. 13 u. 14). Penis am Grunde der Penishülse mit drei Dornen, an der rechten Seite mit einem starken Dorn, der im Bogen hinten um den Penis herumführt (Dorn a). Dieser Dorn trägt am Aussenrand zwei Seitendornen (a_1 u. a_2). Der Endteil von Dorn a ist noch einmal verdickt. Rechts und links am Grunde der Penishülse stehen zwei kurze, nach oben weisende Dornen (b. u. c). Der Dorn b ragt nicht über die Mitte des Penis nach hinten (Abb. 8).

Von der persischen Subspecies *P. fuscofasciatus fuscofasciatus* Mel. unterscheidet sich die aegyptische Subspecies durch Ausbildung der Dornen. Bei der ersteren trägt der Aussenrand des Dorns a nur einen Seitendorn und ist in seiner distalen Hälfte nicht noch einmal verdickt. Der Dorn b. ist wesentlich länger und weist nach hinten. Er überragt die Mitte des Penis. (Abb. 7).

Holotype: ♂, Baharein, 13.6.35. Im Britischen Museum.

Paratypoide: Baharein, 11.6. 2 ♂♂ u. 2 ♀♀, 13.6. 1 ♀; Siwa 9.8. 3 ♂♂ u. 9 ♀♀; Khamissa 29.6. 2 ♀♀, 3.9. 1 ♀; Jagub 18.-19.8. 2 ♀♀; Girba 12.8. 1 ♀; El Arig 8.6. 1 ♂.

Hemitropis seticulosa (Leth.) 1874

1874 *Haplacha seticulosa* Lethierry, Pet. Nouv. Ent. 1: 444.
1876 *Haplacha seticulosa* Fieber, Rev. et Mag. Zool. 3: 166.
1907 *Duilus seticulosus* Oshanin, Verz. Pal. Hem. 2: 249.
1936 *Hemitropis seticulosa* Metcalf, Gen. Cat. Hem. IV (2): 119.

Siwa, 26 ♂♂ u. 15 ♀♀, 28.5. bis 9.8; Ilrhabit Uncorde, 2 ♂♂, 18.5.

Herr Dr. Beier stellte mir freundlicherweise das Material des Wiener Naturhistorischen Museums aus dieser Gattung zur Verfügung, so dass ich hier eine Bestimmungstabelle der nordafrikanischen Arten geben kann.

1'' Nerven der Vorderflügel ohne Kœrnchen. Auf der 3. Endader ein kleiner grauer Fleck, 2 oder 3 ebensolche Flecken auf dem Umfangnerven in der letzten Endzelle. Die senkrecht stehenden Aussenflächen der lateralen Scheitelkiele über den Augen ohne Punkt oder Strichel. Endplatten der Griffel an der vorderen oberen Ecke scharf zugespitzt. Endteil des Penis mit zahlreichen kleinen Dornen besetzt (Abb. 15-19) ..... **bipunctata** Fieb. 1866

1' Nerven der Vorderflügel mit Kœrnchen, Keine Flecken in den Endzellen, oft aber in der vorderen Hälfte der Vorderflügel eine mehr oder weniger deutliche Querbinde. Endplatten der Griffel mit abgerundeten Ecken.

2'' Die Kœrnchen auf der Costa kräftiger und weiter auseinanderstehend als auf den anderen Nerven. Naht zwischen Frons und Clypeus erkennbar. Scheitel zwischen den Hinterecken schmäler als lang. Die senkrecht stehenden Aussenflächen der lateralen Scheitelkiele über dem

Auge oft mit einem kleinen braunen Pünktchen. Fortsatz im unteren Ausschnitt des Genitalsegments viereckig. Afterrœhre auf der Unterseite ohne Anhänge. Endplatten der Griffel viel hœher als breit .... **seticulosa** Leth. 1872

2'' Die Kœrnchen auf der Costa nicht oder wenig kraftiger und ebenso dicht wie auf den anderen Nerven. Naht zwischen Frons und Clypeus undeut-

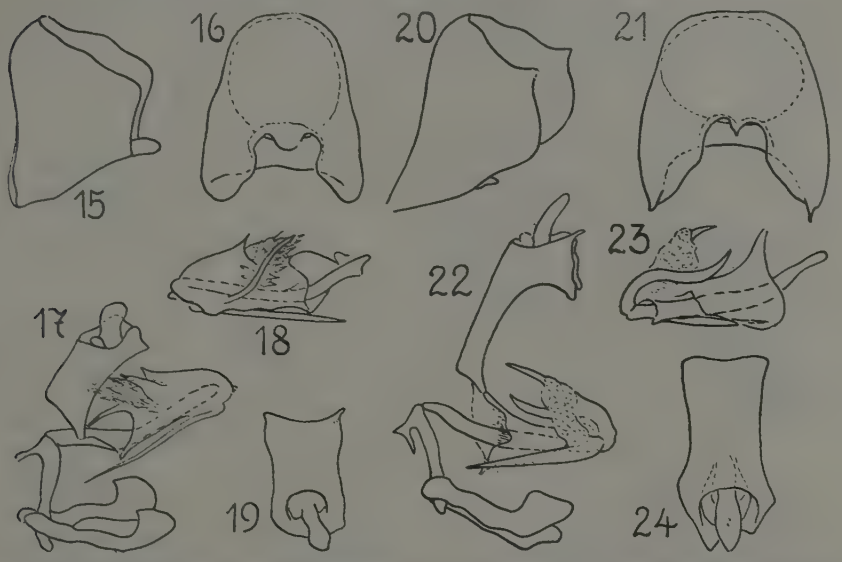


Abb. 15-19.— *Hemitropis bipunctata* Fieb. (Spanien): 15. Genitalsegment seitlich; 16. Dass. von unten; 17. Genitalien von links; 18. Penis von rechts; 19. Afterrœhre von oben.

Abb. 20-24.—*Hemitropis letourneuxi* Leth. (Algerien, Chott Melhir): 20. Genitalsegment seitlich; 21. Dass. von unten; 22. Genitalien von links; 23. Penis von rechts; 24. Afterrœhre von oben.

lich. Die Aussenflächen der lateralen Scheitelkiele über dem Auge mit einem kleinen braunen wagerechten Strich oder ohne Zeichnung. Fortzatz im unteren Ausschnitt des Genitalsegments spitzdreieckig oder abgerundet. Afterrœhre auf der Unterseite vor dem Ende mit zwei dreieckigen Anhängen. Endplatten der Griffel fast so hoch wie breit.

3'' Die Kœrnchen auf den Nerven sehr zart, oft mit den Nerven gleichfarbig. Die Aussenfläche der lateralen Scheitelkiele mit einem waagerechten braunen Strichel. Scheitel zwischen den Hinterecken schmäler als lang, an der Scheitelspitze am schmalsten, dort ungefähr halb so breit wie an den Hinterecken. Der mediane Stirnkiel kräftig, bis zum Clypeus reichend. Genitalsegment am Hinterrand jederseits in eine Spitze ausgezogen. Afterrœhre von oben gesehen hœchstens zweimal so lang wie

breit. Penishülse am distalen Ende jederseits mit einem starken Dorn. ..... **letourneuxi** Put. et Leth. 1887

3' Die Kœrnchen auf den Nerven deutlich braun, dunkler als die Nerven und kräftiger als bei der vorigen Art. Die Aussenfläche der lateralen

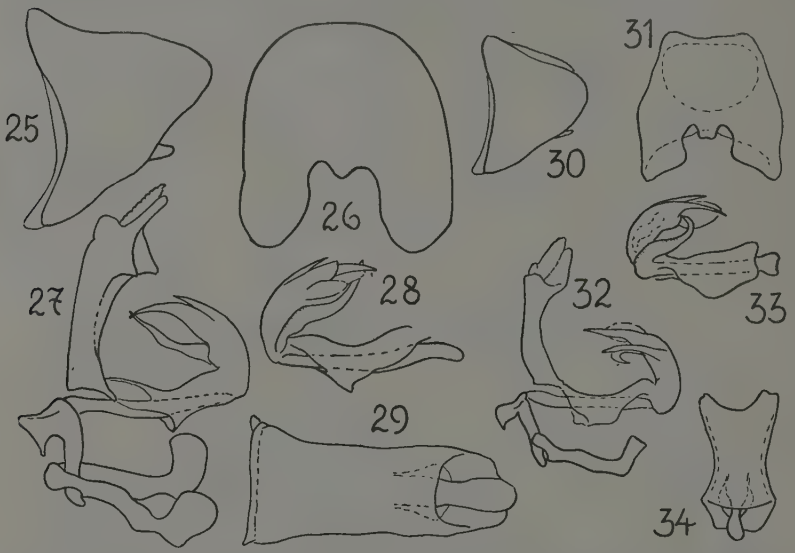


Abb. 25-29.— *Hemitropis arcufera* Put. (Algerien, Chott Melhir): 25. Genitalsegment seitlich; 26. Dass. von unten; 27. Genitalien von links; 28. Penis von rechts; 29. Afterrœhre von oben.

Abb. 30-31. — *Hemitropis seticulosa* Leth. (Sizilien, Catania): 30, Genitalsegment seitlich; 31. Dass. von unten.

Abb. 32-34.— *Hemitropis seticulosa* Leth. (Aegypten, Siwa, Omer-Cooper leg.): 32. Genitalien von links; 33. Penis von rechts; 34. Afterrœhre von oben.

Scheitelkiele über dem Auge ohne Zeichnung. Scheitel in der Mitte am schmalsten, nach vorn und hinten verbreitert. Der mediane Stirnkiel undeutlich, kaum erkennbar. Die Seiten des Genitalsegments hinten abgerundet. Afterrœhre von oben gesehen mehr als zweimal so lang wie breit. Penishülse nur an der rechten Seite mit einem starken Dorn .... **arcufera** Put. 1884

ARAEOPIDAE

Nephropsia tuberipennis Mulsant et Rey 1855

1834 *Fulgura elegans* Costa, Cenni Zool.: 82.
1855 *Delphax tuberipennis* Mulsant et Rey, Ann. Soc. Linn. Lyon 2: 199.
1862 *Nephropsia elegans* Costa, Ann. Mus. Zool. Napoli 1: 77, Tf. 2.
1872 *Tropidocephala elegans* Fieber, Kat. Europ. Cicad.: 5.
1943 *Nephropsia tuberipennis* Metcalf, Gen. Cat. Hem. IV (3): 100.

Khamissa 2 ♂♂ u. 1 ♀, 29.6. bis 3.7; Gara 4 ♂♂ u. 5 ♀♀, 3.7; Siwa 37 ♂♂ u. 11 ♀♀, 10.5. bis 9.8; Tagzertie 2 ♀♀, 12.-13.7.

Calligypona propinqua Fieb. 1866

1866 *Delphax propinqua* Fieber, Verh. Zool. Bot. Ges. Wien 16: 525.
1868 *Delphax hamulata* Kirschbaum, Cicad. Wiesbaden: 38.
1872 *Liburnia propinqua* Fieber, Kat. Europ. Cic.: 5.
1927 *Liburnia albicollis* Haupt (nec Motschulsky), Inst. Agric. Nat. Hist. Bull. Tel Aviv 8: 11.
1935 *Liburnia albicollis* Haupt (nec Motschulsky), Brohmer, Faun. Mittel-
1943 *Delphacodes propinqua* Metcalf, Gen. Cat. Hem. IV (3) : 496.
europa, 4 (3): 144.

Haupt hielt 1927 diese Art für identisch mit *Delphax albicollis* Motsch. 1863, und andere Autoren sind ihm in dieser Auffassung gefolgt. Er begründete seine Meinung damit, dass Beschreibung und Abbildung von

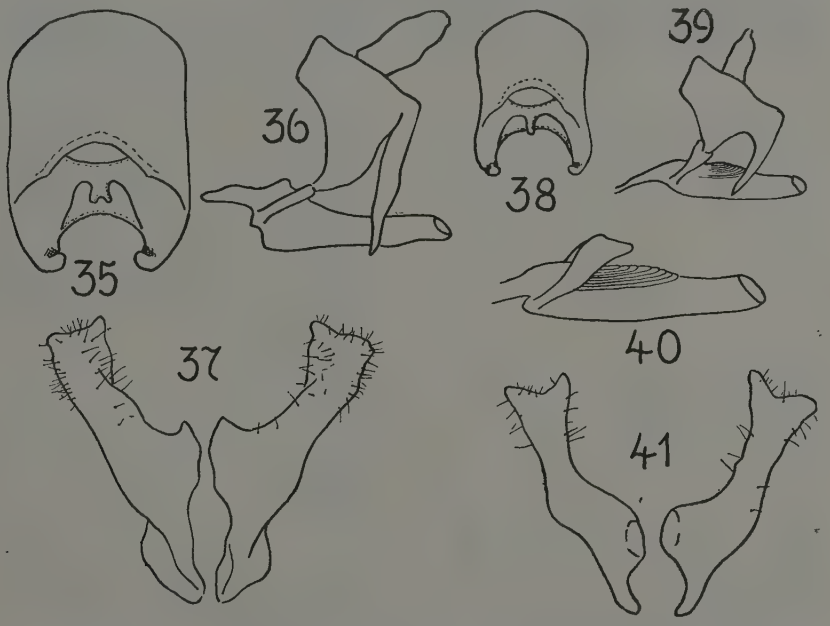


Abb. 35-37.— *Calligypona propinqua* Fieb. (Aegypten, Zeitoun, Omer-Cooper leg.): 35. Genitalsegment schräg von hinten und unten; 36. Aftersegment und Penis seitlich; 37. Griffel, auseinandergebreitet.
Abb. 38-41.— *Calligypona albicollis* Motsch. (Ceylon, Henaratgoda, Coll. Melichar): 38. Genitalsegment von hinten und unten; 39. Analsegment und Penis seitlich; 40. Penis seitlich, stärker vergœssert; 41. Griffel, ausgebreitet.

Liburnia albicollis bei Melicher, 1903, Homopt.-Fauna von Ceylon: 99 und bei Kirkaldy, 1907, Bull. Hawaiian Sug. Pl. Assoc. 3: 161 auf diese Art passen. Dem freundlichen Entgegenkommen von Herrn Dr. Stehlik

habe ich es zu danken, dass ich eine Reihe von Exemplaren, die Melichar aus Ceylon vorlagen, genau untersuchen konnte. Von dem ceylonesischen Material Melichars hat auch Kirkaldy einen Teil gesehen. Die Untersuchung ergab nun, dass die Tiere, die Melichar und Kirkaldy als *D. albicollis* Motch. bezeichneten, nicht zu *propinqua* Fieb. gehœren. Beide Arten unterscheiden sich durch folgende Merkmale:

propinqua Fieb.	*albicollis* Motsch.
Kœrperlänge beim ♂ : 3,4 bis 3,6 mm, beim ♀ : 3,8 bis 4,1 mm.	Kœrperlänge beim ♂ : 2,4 bis 2,6 mm, beim ♀ : 2,6 bis 2,7 mm.
Scheitel- und Stirnkiele gelb, beim ♂ das vordere Scheitelgrübchen und die Stirntälchen schwarz, beim ♀ gelb, aber die Kiele dort schwarz gerandet.	Scheitelgrübchen und Stirntälchen bei beide Geschlechtern mit den Kielen gleichfarbig ockerfarben.
Der übrige Teil des Kopfes, das Pronotum und das Schildchen bei beiden Geschlechtern ockergelb.	Kopf bei ♂ u. ♀ ockergelb. Pronotum bei beiden Geschlechtern weiss, Schildchen beim ♂ pechbraun bis schwarz, beim ♀ ockergelb.
Scheitel so lang wie breit.	Scheitel deutlich länger als breit.
Seitenkiele des Pronotums deutlich nach aussen um das Auge herumgebogen und meistens in einen Kiel mündend, der zwischen Auge und Deckschuppe parallel zum Hinterrand läuft.	Seitenkiele des Pronotums stark divergierend, beim ♂ fast gerade, den Hinterrand fast erreichend, beim ♀ schwach gebogen. Zwischen Deckschuppe und Auge ist beim ♂ und manchmal auch beim ♀ das Stück eines Kieles zu erkennen, das dem Hinterrand parallel läuft. Zwischen diesem und dem Seitenkiel des Pronotums befindet sich stets eine deutliche Lücke.
Durchmesser der Afterrœhre kürzer als ihre Anhänge.	Durchmesser des Afterrœhre länger als ihre Anhänge.
Penis auf der Oberseite glatt.	Penis auf der Oberseite mit mehreren Querfalten, die beiderseits nach vorn umbiegen.
Fortsatz des Genitalphragmas gegabelt.	Fortsatz des Genitalphragmas einfach.
Oberkante der Griffel kaum ausgebuchtet.	Oberkante der Griffel stark ausgebuchtet.

Siwa 31 ♂♂ u. 34 ♀♀, 18.4. bis 6.9.; Maragi 6 ♂♂ u. 4 ♀♀, 14.8. bis 26.8.; Gara 3 ♂♂ u. 1 ♀, 3.-4.7.; Khamissa 2 ♂♂, 3.9; Zeitoun 4 ♂♂ u. 5 ♀♀, 2.9.; Tutnatee 2 ♂♂ u. 1 ♀, 28.6. bis 6.9; Jagub 1 ♀, 18.-19.8 ; ohne nähere Angabe 4 ♀♀, 4.9.

Delphacodes furcifera (Horvath) 1899

1899 *Delphax furcifera* Horvath, Term. Füzetek 22 : 372.
1943 *Liburnia furcifera* Metcalf, Gen. Cat. Hem. IV (3) : 357.

Die vorliegenden ♂♂ stimmen im Bau des Pygophors, des Penis und der Griffel vollkommen überein mit einem Exemplar von *D. furcifera* aus S. Afrika, Zululand, aus dem Britischen Museum, das Herr Prof. China mir freundlichst zur Untersuchung überliess. Sicherlich ist zu dieser weit verbreiteten Art auch zu rechnen: *Liburnia vibix* Haupt, 1927. Wahrscheinlich gehœren auch von den durch Matsumura 1910 (Journ. Coll. Sci. Univ. Tokyo 27: 30-36 beschriebenen Arten einige zu *L. furcifera* Horv. Eine Entscheidung darüber ist jedoch allein nach den Beschreibungen und Abbildungen nicht mœglich.

Siwa 4 ♂♂ u. 5 ♀♀, 22.4. bis 6.7.; Zeitoun 1 ♂, 2.9.

FLATIDAE

Phantia indicatrix Walk. 1870

1870 *Poeciloptera indicatrix* Walker, Zoologist 28: 2403.
1907 *Phantia indicatrix* Oshanin, Ann. Mus. Zool. St. Petersburg 12: 291.
1902 *Phantia indicatrix* Melichar, Ann. Naturhist. Hofm. Wien 17: 12 u. 16.

Siwa 24.4. bis 27.8. 7 Ex.

Eine neue Miriden-Gattung aus Aegypten

[Hempitera-Heteroptera]

(mit 9 Abbildungen)

von Eduard Wagner, Hamburg

Cranocapsus nov. gen.

Gestalt eiförmig, im äusseren Aussehen den Arten des Subgenus *Camptobrochis* Fieb. des Genus *Deraeocoris* Kb. recht ähnlich. Pronotum, Scutellum und Halbdecken mit kräftigen, eingestochenen Punkten bedeckt. Oberseite kahl. Kopf geneigt, von vorn gesehen nur wenig (1,1×) breiter als hoch (Fig. 3); Zügel vorstehend. Stirnschwiele schlank, Gesichtswinkel spitz. Stirn mit 6 in der Mitte unterbrochenen Querlinien, die von dunkel gefärbten Punktgruben gebildet werden. Fühler kurz and kräftig (Fig. 2), die beiden Endglieder nicht fadenförmig sondern spindelförmig und fast so dick wie das 2.

Pronotum mit etwas abgeflachten Hinterecken, die den Grund des Corium nach aussen beträchtlich überragen (Fig. 1); Schwielen getrennt, deutlich. Membranadern wei bei *Camptobrochis* geformt (Fig. 6), gleichmässig gekrümmt, Zellen klein, flach.

Tarsen (Fig. 4) kräftig, das 1. Glied ist das kürzeste und das 3. das längste. Klaren (Fig. 5) mit kräftigem Basalzahn, der etwa bis zur Mitte reicht; der distale Teil der Klauen ist schlank, fäst gerade und nur kurz vor der Spitze stärker gekrümmt.

Im Bau der Genitalien ist die Gattung den Arten des Subgen. *Camptobrochis* gleichfalls recht ähnlich (Fig. 6-9) zeigt jedoch wenig Aehlichkeit mit denen des Subgen *Deracocoris* s. str.

Cranocapsus nov. gen. gehört ohne Zweifel in die Nähe der Gattung *Deraeocoris* Kb. Sie unterscheidet sich jedoch von dieser Gattung dadurch dass der Kopf nicht glatt ist, sondern 6 Reihen eingestochener Punkte aufweist. Dies Merkmal erscheint mir so bedeutend, dass es die Aufstellung eines neuen Genus rechtfertigt. Wenn dieses hier in die Nähe der Gattung *Deracocoris* gestellt wird, so geschieht das vor allem, weil die hier beschriebene Art im übrigen den Arten des Subgen. *Camptobrochis* Fieb. sehr ähnlich ist.

Von den paläarktischen Arten von *Camptobrochis* Fieb. unterscheidet sich unsere neue Gattung vor allem durch die Punktierung des Kopfes, längeren Kopf (Fig. 3), der bei *Camptobrochis* wesentlich breiter als hoch ist, spitzeren Gesichtswinkel, die kurzen, dicken Fühler, deren letzte Glieder bei *Campto-*

brochis stets fadenförmig und weit dünner als das 2. sind, die weit über des Corium nach aussen hinausreichenden Pronotumecken (Fig. 1) und die im basalen Teil geraden Klauen (Fig. 5).

Dem Subgenus *Platycapsus* Reut., das Carvalho (1952) zu *Deraeocoris* stellte, ist unsere neue Gattung gleichfalls sehr ähnlich und stimmt mit ihm im Bau der Fühler und des Kopfes überein, unterscheidet sich aber ebenfalls durch die Punktgruben auf der Stirn, die Pronotumhinterecken und die Länge der Tarsenglieder, von denen das 1. bei *Platycapsus* länger ist als das 2.; auch ist bei *Platycapsus* die Stirnschwiele von der Stirn nicht abgesetzt.

Cranocapsus puncticeps nov. spec.

Klein, oval, 2,25x so lang wie das Pronotum breit ist, hell ockergelb mit dunkel brauner Zeichnung. Oberseits dicht mit kräftigen, eingestochenen dunklen Punkten bedeckt, die auf dem Pronotum am gröbsten und im hinteren Teile der Halbdecken am feinsten sind und an den Rändern in der Regel farblos sind.

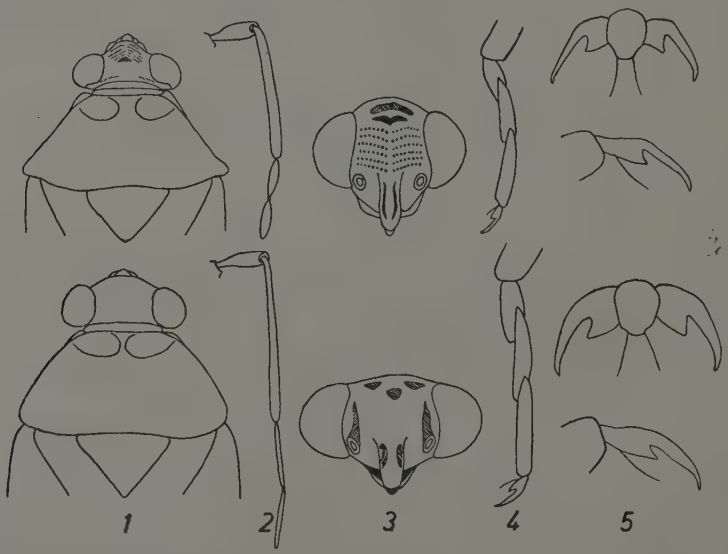


Fig. 1-5. — Deraeocorinae: Obere Reihe = *Cranocapsus puncticeps* nov. spec.; untere Reihe = *Camptobrochis serenus* D. Sc.
Fig. 1 = Kopf, Pronotum und Scutellum von oben (22,5×); Fig. 2 = Fühler des ♂ (22,5×); Fig. 3 = Kopf des ♂ von vorn (31,5×); Fig. 4 = Hinterfuss des ♂ (31,5×); Fig. 5 = Klauen (167×).

Kopf (Fig. 3) verhältnismässig lang, von vorn gesehen kaum breiter als hoch. Stirnschwiele spitz, vorstehend, mit 2 dunklen Längstreifen, von der

Stirn deutlich abgesetzt. Zügel stark vorstehend. Stirn mit 6 braunen Querlinien, die in der Mitte unterbrochen sind und von dunkel gefärbten Punktgruben gebildet werden. Scheitel mit 2 hintereinander liegenden braunen Querflecken, Hinterrand kielartig, vor demselben eine dunkle Quergrube, die in der Mitte flacher ist als an den Seiten. Scheitel (♂) 1,44× so breit wie das vorstehende Auge. Innere Augenränder geschweift, im unteren Teil zurückweichend und dort deutlich weiter von einander entfernt als auf dem Scheitel. Fühler (Fig. 2) kurz und kräftig, fein behaart, gelbbraun; 1. Glied etwa so lang wie der Scheitel breit ist; 2. Glied nur 0,66× so lang wie das Pronotum breit ist, etwa 10× so lang wie dick (bei *Camptobrochis* etwa 15×); 3.+4. Glied spindelförmig, kaum schlanker als das 2. Glied und zusammen nur 0,67× so lang wie das 2.; die Spitze das 2. Gliedes, sowie das ganze 3.+4. Glied etwas angedunkelt.

Pronotum (Fig. 1) mit Ausnahme der Schwielen sehr kräftig punktiert, seine Seiten leicht geschweift; Hinterecken stark vorstehend, in der Mitte des Pronotum eine helle, schwielenartige Längslinie, die sich auf dem Scutellum fortsetzt. Scutellum kräftig punktiert, Spitze glatt und hell; Schildgrund völlig bedeckt, Fläche mit Ausnahme der hellen Mittellinie, je eines Fleckes in den Grundwinkeln und der Spitze braun.

Halbdecken am Grunde kräftiger, distal feiner punktiert. Grund, Mitte und hintere Aussenecke des Corium braun gefleckt; Cuneus im Innenwinkel und distal etwa bis zur Mitte dunkelbraun. Membran hell rauchbraun, die Zellen und ein Fleck hinter denselben glashell; Kubitalader gelblich; Brachialader dunkler, beiderseits dunkel gesäumt.

Unterseite gelbbraun. Beine gelblich, Schenkel vor der Spitze mit 2 braunen Ringen; Schienen am Grunde und an der Spitze schmal dunkel, in der Mitte ein breiter dunkler Ring. Tarsen schlank (Fig. 4), das 1. Glied kurz, das 3. Glied etwa so lang wie die beiden ersten zusammen. Klauen

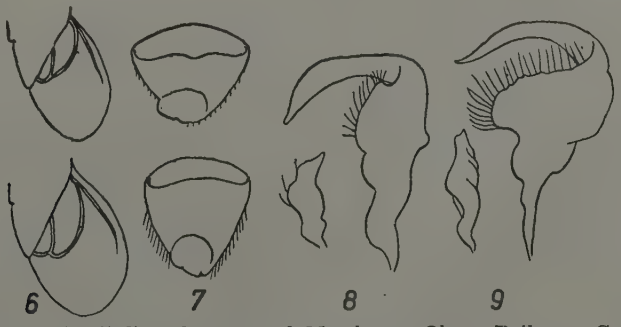


Fig. 6-9. — Genitalien des ♂ und Membran: Obere Reihe = *Cranocapsus puncticeps* nov. spec.; untere Reiche = *Camptobrochis serenus* D. Sc.
Fig. 6 + 7 oben und Fig. 8 = *Cranocapsus puncticeps* nov. spec.; Fig. 6 +7 unten und Fig. 9 = *Camptobrochis serenus* D. Sc.; Fig. 6 = Membran (16×); Fig. 7 = Genitalsegment von oben (22,5×); Fig. 8+9 = Genitalgriffel (84×).

(Fig. 5) schlank, am Grunde mit 1 Zahn, der fast bis zur Mitte reicht, distal schlank und fast gerade. Der Schnabel reicht bis zwischen die Hinterhüften.

Genitalsegment des ♂ (Fig. 7) auffallend kurz und breit, kaum behaart, Rechter Genitalgriffel (Fig. 8) sehr kurz und kräftig stark eingeschnürt. Linker Griffel (Fig. 8) sichelförmig ; Hypophysis lang, leicht gekrümmt, vor der Spitze verbreitert, distal kräftig; Sinneshœcker flach, nach links gewœlbt, verhältnismassig kurz und am oberen Rande mit deutlichem Hœcker, Behaarung kurz und fein. Penis schlank, ohne Chitinstäbe, Ansatzplatten mittelgross, Theca distal stumpf, abgerundet.

Länge: ♂ = 2,97 mm.

Ich untersuchte 1 ♂, das Reimoser bei El-Wasta in Aegypten fing. ♀ bisher unbekannt. Holotypus im Naturhistorischen Museum Wien.

Für die freundliche Zusendung dieses interessanten Tieres bin ich Herrn Dr. M. Beier vom Naturhistorischen Museum Wien zu grossem Dank verpflichtet.

Eine neue *Orius*-Art aus Palaestina

[Hemiptera-Heteroptera: Anthocoridae]

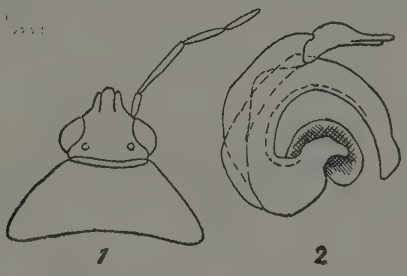
(mit 2 Abbildungen)

von Eduard Wagner, Hamburg

Orius (Heterorius) luridus nov. spec.

Schmutzig ockergelbbraun, oberseits fein hell behaart, matt oder schwach glänzend. Klein, oval, das ♂ 2,6×, das ♀ 2,5× so lang wie das Pronotum hinten breit ist.

K o p f (Fig. 1) deutlich kürzer als breit, gelb bis gelbbraun, so breit wie das braune Auge, Ocellen nahe dem Auge. Fühler gelbbraun, fein hell behaart, das 1. Glied kürzer als das Auge breit ist; das 2. Glied 0,7× so lang wie der Kopf breit ist und nur 0,35× so lang wie das Pronotum breit ist; das 3. Glied etwa so lang wie der Scheitel breit ist, das 4. Glied etwas länger.



O. luridus nov. spec. :

Fig. 1: Kopf, Pronotum und Fühler des ♀ (45×). — Fig. 2: Genitalgriffel des ♂ (150×).

P r o n o t u m (Fig. 1) trapezförmig, mit fast geraden Seiten, die Borsten in den 4 Ecken nicht länger als die übrige Behaarung, Schwielen stark gewölbt, mit einander vereinigt, Seitenrand neben den Schwielen schmal blattartig, hinterer Abschnitt undeutlich gerunzelt.

H a l b d e c k e n matt, glatt, fein behaart, Cuneus in der Regel dunkler. Membran hell gelblichgrau, ungefleckt. Unterseite gelbbraun. Beine hellgelb, alle Schenkel und Schienen gelb.

G e n i t a l g r i f f e l d a s ♂ (Fig. 2) mit sehr langem, schlankem Zapfen, der gegen die Spitze kaum verjüngt und distal schräg abgerundet ist, ohne Zahn auf dem Zapfen; Geissel sehr kurz und kräftig, undeutlich zweiteilig

(vielleicht ist die Spitze der Geissel des einzigen ♂ abgebrochen oder abgefressen).

Länge : ♂ = 1,67 mm, ♀ = 1,55-1,65 mm.

O. luridus n. sp. gehœrt in die Untergattung *Heterorius* E. Wagn., da die Borsten in den Vorderecken des Pronotum kurz sind. In der Färbung ähnelt er *O. discolor* Reut., unterscheidet sich aber von dieser Art durch die geringe Grœsse und den langen, schlanken Zapfen des Genitalgriffels. Auch die übrigen Arten der Untergattung *Heterorius* sind weit grœsser, sind fast immer zum grœssten Teil schwarz gefärbt und haben ganz anders gebaute Genitalgriffel. Eine derart helle Färbung wie bei unserer neuen Art findet sich auch bei *O. pallidulus* E. Wagn. und *O. retamae* Noualh. Beide haben jedoch sehr lange Borsten in den Pronotumecken, weit kürzere Fühler, vor allem das 2. Glied ist kürzer und einen Zahn auf dem Zapfen des Genitalgriffels.

Ich untersuchte 1 ♂ und 2 ♀♀ aus Palästina: Wadi Buscara, U. Sahlbg. leg.

Holotypus in meiner Sammlung, Allotypoid und Paratypoid in der Sammlung der Universität Abo.

Herrn R. Linnavuori, Abo, der mir die Tiere zusandte, sei auch an dieser Stelle bestens gedankt.

Blepharidopterus (Aetorrhinus) dubius nov. spec.

[Hemiptera-Heteroptera: Miridae]

(mit 11 Abbildungen)

von Eduard Wagner, Hamburg

Gestalt langgestreckt, das ♂ 5,1×, das ♀ 4,5× so lang wie das Pronotum hinten breit ist. Glänzend, im Leben hellgrün bis sattgrün, mit halbaufgerichteten, langen schwarzen Haaren zerstreut bedeckt. Fühler und Beine sehr lang.

Kopf (Fig. 2 + 5) kurz, von oben gesehen weit breiter als lang. Hinterrand des Scheitels gekielt, davor eine Querrinne. Scheitel beim ♂ 0,92×, beim ♀ 1,78× so breit wie das grob gekœrnte, dunkle Auge. Stirnschwiele vorstehend, oft schwarz gefleckt. Fühler sehr lang, mit feinen, kurzen, dunklen Haaren bedeckt; 1. Glied an Grund und Spitze schmal weisslich, schwarz-

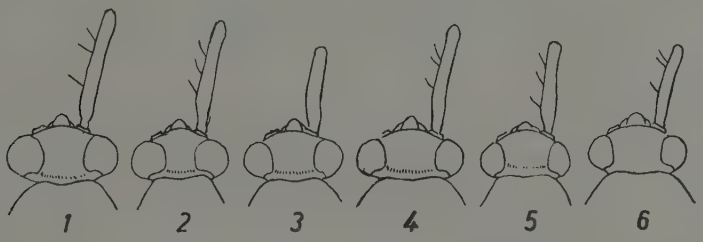


Fig. 1-6: *Blepharidopterus*, Kopf und 1. Fühlerglied (22,5×) : Fig. 1-3 = Mannchen; Fig. 4-6 = Weibchen; Fig. 1 + 4 = *B. angulatus* Fall.; Fig. 2 + 5 = *B. dubius* nov. spec.; Fig. 3 + 6 = *B. brevicornis* E. Wagn.

braun, in der Mitte breit aufgehellt, an der Innenseite des Gliedes 2-3 kräftige Borsten, das Glied ist beim ♂ + ♀ etwa so lang wie der Kopf samt Augen breit ist; 2. Glied lang stabfœrmig, 2,4-2,5× so lang wie das 1. und beim ♂ 2,3×, beim ♀ 1,8× so lang wie das Pronotum hinten breit ist; grünlich oder bräunlich, bisweilen schwarzbraun, am Grunde stets schmal schwarz; das 3. Glied deutlich kürzer als das 2., leicht gekrümmt, beim ♂ 0,87×, beim ♀ 0,88× so lang wie das 2. und beim ♂ 1,57×, beim ♀ 2,0× so lang wie das Pronotum hinten breit ist; 4. Glied sehr kurz, 0,5-0,6× so lang wie das 1.

Pronotum glockenfœrmig, Hinterecken mit schwarzem Fleck, Schwielen gewœlbt, in der Mitte aneinanderstossend. Schildgrund frei.

Halbdecken etwas dichter aber feiner behaart, die Haare bräunlich, Aussenrand des Corium und Subcostalader oft dunkelgrün. Membran hell rauchgrau, Adern grünlich oder gelblich. Die beiden kleinen Flecke neben der Brachialader fehlen oder sind sehr undeutlich; hinter der Spitze der grossen Zelle ein dunkelgrauer, nach hinten verbreiterter Fleck.

Unterseite grün, fein hell behaart. Bein gelblich oder grün, fein hell behaart; Schienen hell bedornt, am Grunde aussen mit schwarzem Fleck. Hinterschiene beim ♂ 2,9×, beim ♀ 2,6× so lang wie das Pronotum hinten breit ist. Tarsen schlank, schwarz, proximal bisweilen heller. Der Schnabel reicht bis zwischen die Hinterhüften.

Genitalsegment des ♂ (Fig. 7) stumpf kegelförmig, distal breit abgerundet mit langen, feinen Haaren bedeckt. Rechter Genitalgriffel (Fig. 8) schwarz gefärbt, nur proximal hell, löffelförmig, lang gestielt, hinter der

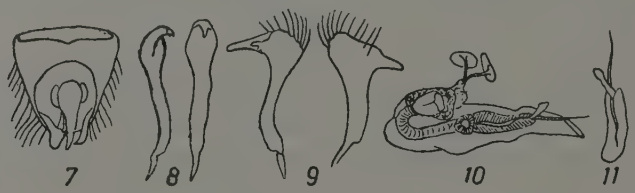


Fig. 7-11: *B. dubius* nov. spec., Genitalien des ♂:
Fig. 7 = Genitalsegment von oben (31,5×); Fig. 8 = rechter Griffel (linksseitlich, rechts = von innen, 84×); Fig. 9 = linker Griffel (links = von links, rechts = von rechts, 84×); Fig. 10 = Penis von rechts (84×); Fig. 11 = Chitinstäbe der Vesica (84×).

Mitte leicht eingeschnürt und dann verbreitert, Hypophysis gross, spitz, stark nach innen gekrümmt. Linker Griffel (Fig. 9) schmal, hakenförmig gebogen, Paramerenkörper proximal schlank, gekrümmt, distal kopfartig gebogen aber abgerundet, dicht behaart, Hypophysis kurz und kräftig, leicht abwärts gerichtet, hell gefarbt; Sinneshöcker gerundet, mit einem nach innen gerichteten, kräftigen Fortsatz, unter dem einige kleine Zähnchen sitzen. Penis (Fig. 10) sehr lang und schlank, Theca distal spitz, Ansatzplatten klein. Vesica mit 3 Chitinstäben (Fig. 11), der längste sehr schlank und leicht gekrümmt, der 2. nach oben gebogen, distal verbreitert und dort fein gezähnt, der 3. blattartig, kurz und schmal, distal abgerundet.

Länge: ♂ = 4,7-0,5 mm, ♀ = 4,1-4,4 mm.

B. dubius n. sp. steht *B. angulatus* Fall. nahe, ist aber von weit kleinerer, schlankerer Gestalt. Bei *B. angulatus* ist das ♂ 5,1-5,9 mm, das ♀ 5,2-5,5 mm lang; der Scheitel ist hier beim ♂ 0,94 ×, beim ♀ 1,67× so breit wie das stärker vorstehende Auge (Fig. 1 + 4), das 2. Fühlerglied ist beim ♂ 2×, beim ♀ 1,7× so lang wie das Pronotum hinten breit ist; die Hinterschiene ist hier beim ♂ 3,1×, beim ♀ 2,7× so lang wie das Pronotum breit ist; das Genitalsegment ist distal sehr spitz, der rechte Griffel ist distal weniger stark

verbreitert, der linke Griffel hat eine weit längere, schlankere Hypophysis und auf dem Sinneshœcker nur eine Anzahl kleiner Zähne. Der Penis ist breiter, von den Chitinstäben der Vesica ist der 3. weit länger als der 2.

B. brevicornis E. Wagn. ist von kleiner breiter Gestalt, das ♂ 4,4×, das ♀ 4,2× so lang wie das Pronotum breit ist, der Scheitel ist beim ♂ 1,4×, beim ♀ 1,75× so breit wie das weit kleinere Auge (Fig. 3 + 6); das 1. Fühlerglied ist kurz und beim ♂ 0,85×, beim ♀ 0,76× so lang wie der Kopf samt Augen breit ist; das 2. Glied beim ♂ 1,67×, beim ♀ 1,3× so lang wie das Pronotum breit ist. Der Schnabel reicht nur bis zu den Mittelhüften und die Hinterschiene ist beim ♂ 2,6×, beim ♀ 2,3× so lang wie das Pronotum hinten breit ist. Auch die Genitalien das ♂ sind anders gebaut.

Ich untersuchte 5 ♂♂ und 2 ♀♀ von der Insel Zypern, die Herr Dr. H. Lindberg im Troodos-Gebirge: Prodhomos 19.6.39 (3 ♂♂, 1 ♀), 15.-23.6.39 (1 ♂) und bei Stavros 18.-19.7.38 (1 ♀) und Platania 18.6.39 (1 ♂) fing.

Holotypus und Paratypoide in der Sammlung H. Lindberg in Helsingfors, Allotypoid und Paratypoide in meiner Sammlung.

Herrn Dr. H. Lindberg, Helsingfors sei auch an dieser Stelle für seine liebenswürdige Unterstützung bei meinen Arbeiten recht herzlich gedankt.

A study of the Banana aphid, *Pentalonia Nigronervosa* Coq.

[Hemiptera Homoptera : Aphididae]

(with 11 Text-Figures)

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Entomology Department,
Faculty of Science, Alexandria University

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I. INTRODUCTION

The aphid *Pentalonia nigronervosa* Coq. is the vector of the banana bunchy-top, a virus disease of common occurrence in Egypt. The enormous loss caused to banana cultivation by this virus, necessitated the study of the role of this insect in its transmission as well as the effective methods of control of the aphid.

Since no effective control of the disease can be achieved unless based on scientific sound basis, it was found essential to study this aphid and its activity in connection with disease transmission.

II. MATERIALS AND METHODS

1. The study of the morphology

In studying the life-history of the aphid, many difficulties were faced as the insect is extremely agile and very sensitive. Insect-tight leaf-cages (Fig. 1) were used for rearing purposes. These cages, though insect-tight, were not satisfactory when used during the summer due to the excessive transpiration of the plant leaves, thus causing an increase in the humidity of the atmosphere in the cages to such an extent that resulted in a high mortality of the aphids. Cork cages placed on the pseudostem itself around the aphids, kept in position by the fine insect pins and covered with very thin cloth were used for the same purpose. Observations on free aphids were also made.

Aphids were also reared on separate banana leaf-parts dipped in Tottingham's nutrient solution prepared according to the following formula :

Sodium nitrate 2.0 gms.; disodium phosphate (hydrated) 0.2 gm.; monosodium phosphate (hydrated) 0.1 gm.; potassium chlorate (hydrated) 0.4 gm.; calcium sulphate (hydrated) 0.2 gm.; magnesium sulphate (hydrated) 0.2 gm.; ferric citrate (5 cc. per litre of a 1 % hot solution) ; water up to one litre.

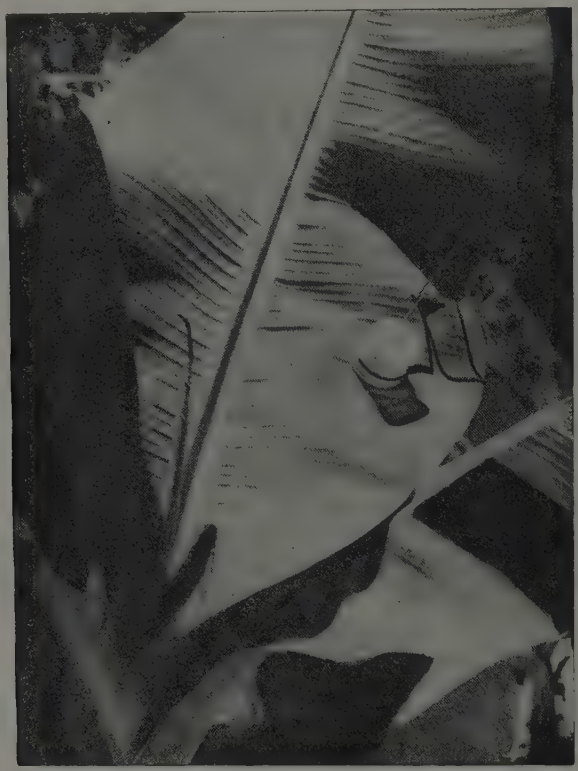

Fig. 1 : One of the insect-tight leaf-cages used in aphid rearing experiments.

The various stages of development of the aphid were fixed in 96 % ethyl alcohol and then mounted in diaphane (a new mounting medium with 96 % ethyl alcohol being its solvent). Camera lucida drawings were taken for each stage.

2. The study of the bionomics

During the study of the biology of the aphid, regular field trips were made to the neighbouring banana plantations at Smouha, Schutz and Victoria (all of which are in the vicinity of Alexandria). In each of these trips, careful readings of humidity and temperature were recorded, observa-

Fig. 2 : An aphid colony reared on a banana plant (notice their aggregation at the leaf base and along the midrib).

tions on the habits and nature of the insects were made and samples of aphids were collected and studied. At the same time we recorded data on aphid colonies raised in the Faculty garden on *Musa* plants (Fig. 2).

3. The study of the feeding habits and feeding mechanism

During the present investigation, aphid colonies feeding on *Musa cavendishii* Lam. were killed in situ by exposure to chloroform vapours. The in-

fested plant tissue is then fixed in F.A.A. fixative (a mixture of formalin, acetic acid and ethyl alcohol), then dehydrated as usual, embedded in paraffin and cut at a thickness of 14 microns, and then stained in safranin (light green stain). The safranin used is composed of a mixture of one part one per cent watery solution and one part of one per cent alcoholic solution of safranin. In this mixture the slides were left for about five to ten minutes. The most satisfactory results are obtained when using the light green solution at a concentration of 0.2 % in which the slides were dipped for three to six seconds.

III. SYSTEMATIC POSITION

Classifications of this aphid were given by Baker (1920), Froggatt (1923), and Hottes and Frison (1931). However, we have followed the system adopted by Baker.

IV. GEOGRAPHICAL DISTRIBUTION

The banana aphid is widely distributed all over the world, wherever its host plants are available. Smith (1937) presented a distribution list of this aphid in which he recorded that it was reported from a number of countries by various authors.

It is not known exactly when it was first reported from Egypt. However, Hall (1926) noted its presence in July of 1926 on bananas planted in this country.

V. HOST RANGE

Pentalonia nigronervosa Coq., living on a very limited host range of the family *Musaceae,* is very specific in its feeding, a fact that makes it easier to control this aphid, especially in Egypt where the wild *Musa* species are absent and the aphid is found only on cultivated banana plants.

Several trials were previously made to detect the host range of the banana aphid. Except for plants of the genus *Musa,* aphids could not establish themselves on any of the plants tested, even on those which are closely related to bananas. On *Canna,* the aphids subsisted only for about one week. On *Strelitzia,* they remained for a slightly longer period after which they perished completely.

The banana aphid, however, was observed by some authors on wild banana (*Heliconia bahai*) and other monocots. Wolcott (1933) recorded its presence on imported *Calla* flowers in Porto Rico. Ocfemia and Buhay (1933), in the Philippine Islands, observed it on *Hedychium coronarium* Kolling (Zingibariaceae).

In the present investigation, trials to breed the banana aphid on *Canna* and *Strelitzia* were carried on at a temperature ranging between 20-22° C. and a humidity from 50-60 %. Such trials were unsuccessful as the insects perished completely after a period of about five days on both plants. This peculiar phenomenon may be attributed to the variations in the pH. value of the cell sap of different plants.

VI. LIFE-HISTORY

The life-history of the banana aphid, *Pentalonia nigronervosa* Coq., has never been perfectly studied before the present work. It has been noticed that this aphid is present on its single host, the banana, all over the year round. During winter months that possess moderate temperatures, the maximal activity of the aphid occurs. During these months dissemination generally takes place, helped by the production of a greater number of alates in this period than during the rest of the year. As noticed in the field this aphid is not a typical migratory one. No seasonal migration from banana to other hosts is noticed.

No egg stage could be detected during the present investigation, a fact which suggests that this aphid is completely a viviparous parthenogenetic one. The different aphid forms which can be detected are only the apterous and alate adult females and their developmental instars. These forms occur on the host plant all over the year with a tendency to increase in numbers in the wet months of the year.

VII. MORPHOLOGY

The necessity of having a fair acquaintance with the morphological characterestics of the different developmental stages of aphid vectors for investigating the importance of each in virus transmission, has been previously referred to by Soliman (1951).

The possibility of using the characterestic features of early developmental stages of aphids in classification has been cleared out by Sampson (1946).

Both of these points of view have called the attention of the author to the importance of carrying on the present detailed morphological study of the banana aphid. Such study has never been done before.

The morphology of the adult aphid vector, *Pentalonia nigronerrosa* Coq., attracted the attention of several earlier investigators among whom are Coquerel (1859), Wilson (1909), Baker (1920), Magee (1927), Zeck and Eastwood (1929), and Hottes and Frison (1931). The descriptions given to this aphid species by these authors, however, were very brief and they all overlooked the general interrelationships between the parts used in taxonomy. A rather detailed description of the different forms of this aphid was made during the present study and is presented here.

1. Morphology of the adult

a. The apterous adult female (Fig. 3)

The apterous adult female aphid has an oval body. It is dark brown to black in colour. Owing to this dark colour of the body, it is rather difficult to detect the youngs within. Antennae are usually longer than the body and of the typical type consisting of six segments. The basal or proximal segment (the scape) is highly gibbous with the antennal tubercles considerably converging and myxus-like in appearance. The next or second segment, the pedicel, is the smallest, barrel shaped and usually carries no sensoria. The third segment is the most developed one. The next two segments, the fourth and fifth are nearly of equal size. The fifth carries at its distal end a sensorium. The distal most segment, the sixth, consists of two divisions : a basal one with a sensorium at its distal extremity, and a terminal long filamentous part which shows imbrications all over its length.

Fig. 3 : The apterous adult female.

Eyes are well developed with black pigmented areas and with the ocular tubercle highly developed. The rostrum is also well developed and reaches the second abdominal segment. The three pairs of legs are well developed, with the femora and tibiae darker in colour. They are furnished with fine hairs and bristles. Tarsi are of two segments and each tarsus supplied with two claws. Cornicles are elongate with imbrications all over their length and with their distal end of somewhat darker colour. They possess a constriction in their middle beyond which they become swollen again. Eash cornicle becomes constricted again just before its end. The cauda is generally spindle

shaped, but with a blunt end. It possesses a constriction at its proximal one third, becomes swollen again and then tapers to give its conical hinder two-thirds. The relation between these different parts can be easily grasped from a comparison of their measurements given below.

Measurements (average of ten measurements): Antennal segments: I, 168 μ, basal segment highly gibbous, even more than in the alate form ; II, 96 μ, possesses no sensoria; III, 352 μ, the longest segment, but also with no sensoria; IV, 256 μ, with no sensoria; V, 240 μ, with one sensorium at the distal end; VI, basal part, 112 μ, carries one sensorium at its junction with the filamentous part; VI, filamentous part (ungus), 736 μ, long and shows constrictions; whole antenna, 1960 μ, longer than body; body (from tip of head to tip of cauda) 1568 μ, shorter than the antenna; cornicle, 368 μ, relatively long with a constriction in the middle; cauda, 192 μ, subconical with a constriction in the upper third; part of cauda that appears behind the anal plate, 64 μ, with a blunt end; tibia of hind leg, 1248 μ, long with hairs and bristles; rostrum, 888 μ, reaches the coxal end of the second abdominal segment.

b. The alate adult female (Fig. 4)

Not only does the alate adult female aphid differ from the apterous one in the possession of wings, but also in the colour, shape of the body and number of sensoria on the antenna. The general shape of the body is elon-

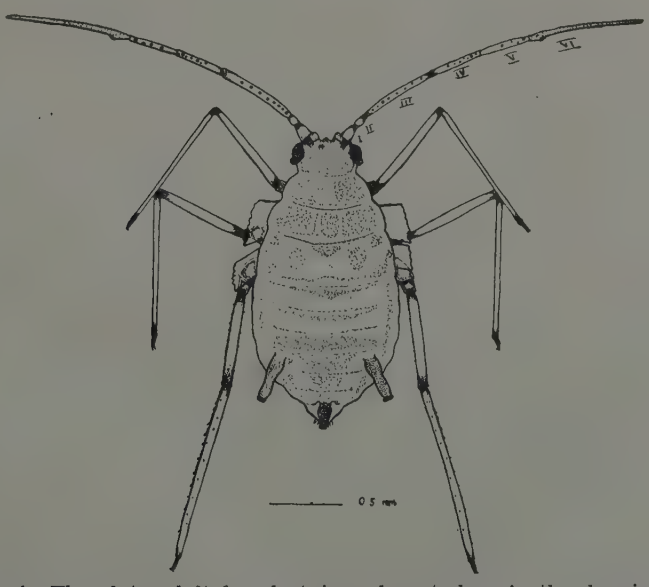

Fig. 4 : The alate adult female (wings do not show in the drawing).

gated, nearly spindle-shaped, and black in colour. Each of the antennal segments from three to six inclusive, carries a number of sensoria. The first two segments, however, carry none. The first segment is gibbous with two converging antennal tubercles. The second segment is stouter than that in the apterous female. The third segment is again the longest, most developed and with the maximal number of sensoria. It bears from six to eleven with an average of nine circular to sub-circular sensoria. These, vary in size and are arranged in more than one straight line. They have a tendency to be crowded at the distal two-thirds of the segment. The next two successive segments, namely the fourth and fifth, are nearly of the same size but differ as to the number of sensoria they possess. The fourth carries from four to six sensoria while the fifth has only two in addition to the primary sensorium existing at its distal extremity. The last segment bears one primary sensorium at the junction of the stout basal part with the filamentous section (the ungus) which shows constrictions all over its whole length. Eyes are

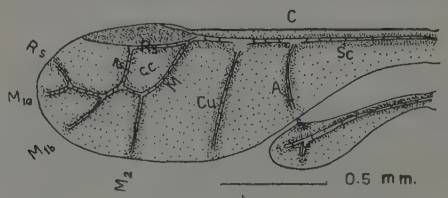

Fig. 5 : Top view of the left pair of wings showing the wing venation.

black with the ocular tubercles well developed. Wing veins of the two pairs (Fig. 5), are dusky with brown borders and easily distinguished by the naked eyes. Wing venation has a peculiar feature which is the formation of a closed cell beneath the stigma. This results from a coalescence of the radial sector, which curves abruptly downwards, with the anterior division of the media. Cubitus and anal veins are simple. The hind wing is very much reduced and contains only one principal vein which represents a group of fused veins. To the costal edge there is a hook, the hamulus, by which the hind wing is attached to the fore wing during flight.

As in the viviparous apterous females, the cornicles are somewhat elongated with a constriction in the middle beyond which they become swollen again. Ornamentations of the imbricate type are scattered along its whole length. The cornicle is darker in colour at its distal extremity. Cauda is long and narrow with a constriction in the upper one third. It possesses three pairs of fine hairs at the tip of the part that appears beyond the anal plate and which ends bluntly. Legs are well developed and long, with their distal extremeties darker in colour. Tarsi of two segments, each of which with two claws. These features are summarized hereunder.

Measurements (average of ten measurements) : Antennal segments: I, 164 μ, gibbous with converging tubercles; II, 80 μ, stout with no sensoria; III, 376 μ, with an average of nine sensoria; IV, 248 μ, with an average of six sensoria; V, 240 μ, carries two secondary and one primary sensorium; VI, basal part, 80 μ, bears one primary sensorium at its distal end; VI, ungus, 760 μ, long and shows constrictions; whole antenna, 1948 μ, relatively longer than body; body, 1648 μ, from tip of head to tip of cauda is shorter than the antenna; cornicle, 288 μ, with a constriction in the middle; cauda, 180 μ, more or less long and narrow, subconical with a constriction in the upper part; part of cauda beyond the anal plate, 90 μ, carries three pairs of curved fine hairs; tibia of hind leg, 1008 μ, provided with hairs and bristles along both sides; rostrum, 880 μ, reaches the first abdominal segment.

2. Morphology of the first to fourth nymphal instars

During its life-history, from the time it is born to the time it reaches maturity as an adult apterous or alate female, the aphid vector passes through five instars with four nymphal stages. Each of the nymphal instars durates about 2-5 days at a temperature of 20-24° C. and about 50-65 % humidity after which the nymph moults, changing into the next instar. The nymphal stage possessing wing pads is called in aphid terminology the pupa and gives rise to alate females.

Similar to the case in all other aphid species, the different instars vary considerably in their morphology. The main differences lie in the general shape of the body and the relation between the different body structures. A detailed description of each stage may not seem worthy of going through, yet a fair knowledge of the characteristics of each is fundamental for any investigator interested in transmission work. Reasons of importance of such study in this type of experiments were refered to by Soliman (1951) who stated that the detection of stages on basis of their morphology is an accurate and time-saving technique which should replace the rearing method.

Detailed morphological studies of the different instars may also help aphid systematists in basing their new phylogenetic systems of classifications on the characters of the immature insects. This idea was thought of by some authors among whom are Bœrner (1930) and Sampson (1946). The latter author was able to formulate a system of classification of aphids based on the morphological characteristics of their first nymphal instar.

For such reasons, the results of a detailed study of the different stages carried on, are presented here. These descriptions, although not fully complete, proved to be of great use for the identification of the various stages.

a. First nymphal stage (Fig. 6)

The newly born insect is a very tiny creature of pale yellow-brownish colour. It is often seen sticking to the mother aphid although it is ready

to crawl when slightly disturbed. It begins feeding soon after birth aided by its extremely long proboscis. The body of the insect is elongate with inconspicuous hairs all over its length. The head carries two compound eyes which still lack the ocular tubercles. The front is rounded and the frontal or antennal tubercles are converging and conspicuous. Antennae are gibbous with only four segments. The two distal segments are well developed and each of which with one poorly developed sensorium. Ungus is extremely long

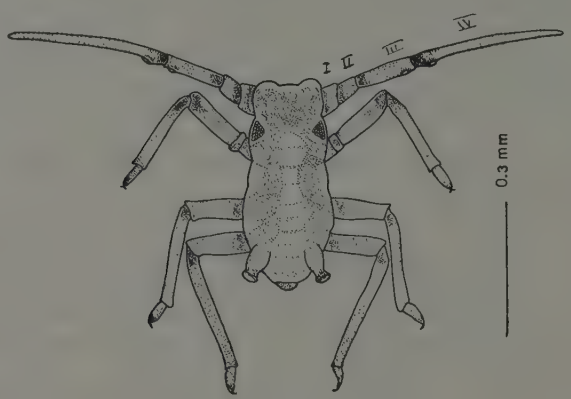

Fig. 6 : The newly born first instar.

showing constrictions. Rostrum is very well developed and extends up to the cornicles near the tip of the abdomen. Cornicles are somewhat short and broad with a very slight constriction in the middle. The upper or distal portion is usually swollen. Cauda is very small and difficult to detect. The anal plate is small and rounded, with two long setae. The description of most of these features is in agreement with what was given by Sampson (1946).

Measurements (mean of ten specimens) : Antennal segments I, 96 μ, gibbous nature is detected, tubercles converging; II, 48 μ; III, 176 μ, the longest segment and carries a poorly developed primary sensorium at its distal end; IV, basal part, 64 μ, carries one primary sensorium at its union with the filamentous part; IV, filamentous part, 348 μ, shows constrictions; whole antenna, 786 μ, longer than abdomen; body, 624 μ, from tip of head to tip of cauda is shorter than antenna; cornicle, 112 μ, shorter than the breadth of the head between the eyes (208 μ), considerably broad with a constriction in the middle; cauda, 18 μ, very blunt, hardly detectable; tibia of hind leg, 400 μ, with fine hairs and bristles; rostrum, 448 μ, extremely long, usually reaching near the end of the abdomen up to the two cornicles.

b. Second nymphal stage (Fig. 7)

The insect in its second nymphal instar has greatly differed in shape and size from the first one. The body is now almost oval and has considerably grown. Antenna is still four segmented with the two sensoria detected in the first instar present and antennal tubercles well pronounced. The colour of the body has greatly changed becoming darker brownish. Distal parts of the legs begin to attain a somewhat darker colour. Cauda is still blunt. Cornicles have their middle constriction easily distinguished and their distal end somewhat darker in colour.

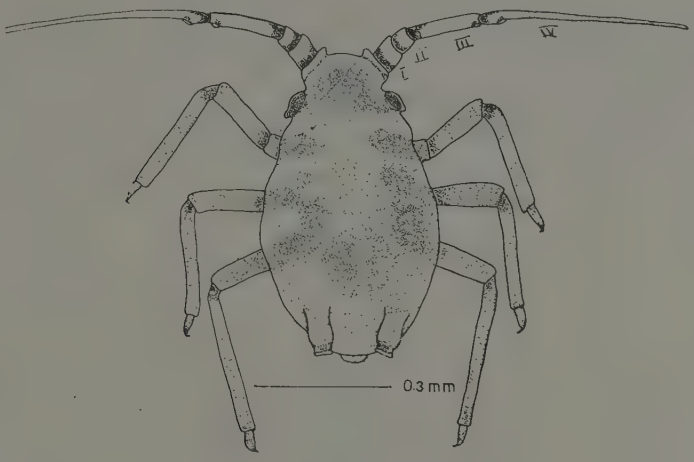

Fig. 7 : The second nymphal instar.

Measurements (average of ten samples): Antennal segments : I, 128 μ, gibbous nature well pronounced; II, 56 μ; III, 208 μ, most developed segment with one primary sensorium at its distal end; IV, basal part, 64 μ, carries a sensorium at its junction with the filamentous end; IV, filamentous part (ungus), 432 μ, very long with constrictions; whole antenna, 888 μ, slightly longer than the body; body (from tip of head to tip of abdomen), 848 μ, slightly shorter than antenna; cornicle, 128 μ, considerably broad with a slight constriction in the middle; cauda, 22 μ, still very small with a blunt end; tibia of hind leg, 416 μ, supplied with delicate hairs and bristles; rostrum, 464 μ, reaches the anterior end of the third abdominal segment.

The insect in this stage greatly resembles that of the late first and early third nymphal stages but the differences present can be easily grasped when each is closely examined.

c. Third nymphal stage (Fig. 8)

The insect at this stadium greatly resembles the late second instar, but the division of the third antennal segment, which has just started at the close of the latter stage, is now perfectly completed resulting in the appearance of the antennal segment number four. Thus, at the present stage, the antenna contains five segments. The insect in the present stage is somewhat darker in colour and durates for a somewhat longer period than the preceeding two instars. Both the gibbous nature of the first antennal segment and the ocular tubercles are now well developed and much more pronounced than before. The body has attained the oval shape characteristic of the adult. The constriction seen in the middle of the adult cornicles is now quite obvious and the cornicles themselves have attained a considerable length with their distal ends beginning to show the darker colour. Cauda is still small, conical and with a blunt end. Legs are well developed and carry on the tibiae the few delicate hairs that will be seen in the adult but do not yet clearly

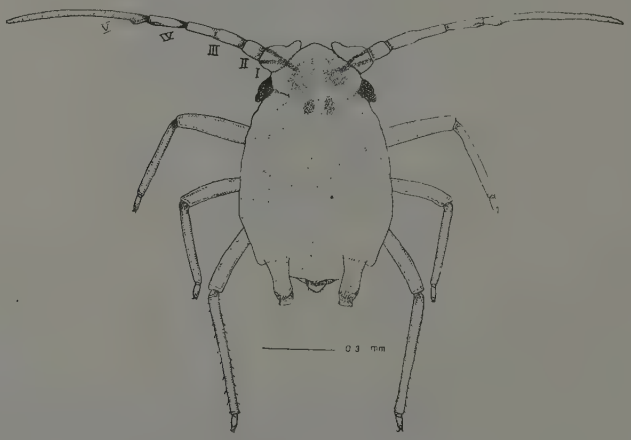

Fig. 8 : The third nymphal instar.

show the dark tinge at the distal tips of the femora and tibiae. The tarsi show the indication of division into two segments with two well developed claws of a darker colour. The anal plate with its pronounced round tip is now better distinguished than in the preceeding stages.

Measurements (mean of ten individuals) : Antennal segments : I, 136 μ, gibbous nature already seen; II, 64 μ, stout and barrel shaped; III, 272 μ, most developed segment, first indications of division into two segments seen later in the stage; IV, 144 μ, provided with a primary sensorium at its distal end near the junction with the fifth segment; V, basal part, 80 μ, of the same thickness as the antenna, with a primary sensorium at its

union with the filamentous part; V, filamentous part, 512 μ, very well developed, thinner than the rest of the antenna, with constrictions; whole antenna, 1208 μ, longer than the body; body (from tip of head to tip of cauda), 869 μ, shorter than antenna; cornicle, 208 μ, constriction is seen, basal part is swollen, darker and has not yet attained its full length; tibia of hind leg, 608 μ, provided with fine hairs and bristles; cauda, 36 μ, still very small but conical in shape, with a blunt end; rostrum, 576 μ, well developed, reaches the fourth abdominal segment.

d. Fourth nymphal stage (Fig. 9)

By this stage, the insect has moulted three times after which it possessed nearly all the characteristics of the adult. Except for the size at this stage, the insect exactly resembles the adult apterous female. All the adult features, including the dark colour, the oval body, the presence of six antennal segments and the dark colour at the tips of the femora and tibiae, can be easily distinguished at this stage. Similar to the third instar, this one durates for a comparatively long time reaching about four days. During this period, the insect attains the full size. It then moults once, thus becomes an adult apterous female insect.

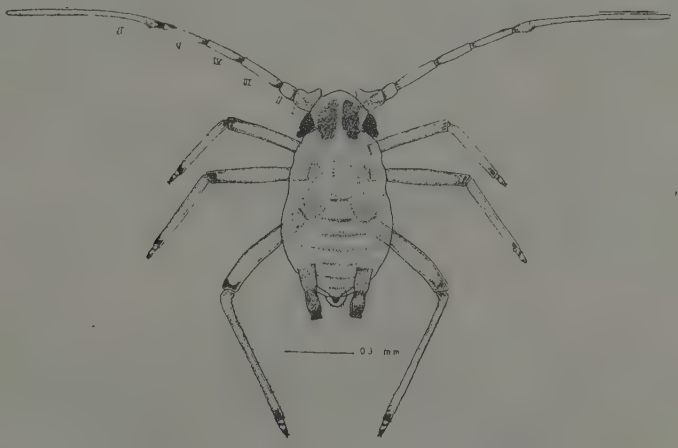

Fig. 9 : The fourth nymphal instar.

The division of the third antennal segment, which has already started late in the preceeding stage, is now completed but the full growth of the segment is not yet attained. However, the antennal and ocular tubercles have already reached their maximal growth. The distal tips of the femora and tibiae are here darker in color than before. The cauda has attained a considerable length with a constriction at the end of its anterior one third ;

the posterior two thirds are conical in shape ending bluntly. The cornicles have already attained their full length, their dark tips and their clear ornamentations. The anal plate is easily distinguished although greatly covered by the cauda.

Measurements (mean of ten measurements) : Antennal segments : I, 144 μ, gibbous nature of the basal part is very well developed; II, 72 μ; III, 76 μ, the newly formed one nearly smaller or of the same length as the following one; IV, 180 μ, nearly of the same length as the preceeding one (III); V, 148 μ, well developed, with a sensorium near its distal tip; VI, basal part, 88 μ, small, with a sensorium at the junction with the filamentous part; ungus, 250 μ, extremely long, flamentous and shows constrictions; whole antenna, 1328 μ, longer than the body; body (from tip of head to tip of cauda), 1008 μ, shorter than antenna; cornicle, 240 μ, long with a constriction in the middle and a swollen distal darker part; tibia of hind leg, 656 μ, very long and dark in colour at its distal tip, furnished with fine hairs and bristles; cauda, 64 μ, attained considerable growth although not yet appearing beyond the anal plate; proboscis, 640 μ, reaches the fourth abdominal segment.

3. The pupal instar (Fig. 10)

Normally the fourth nymphal stage gives rise to apterous adult females. Alate females, however, are given off from a special type of nymphs, those

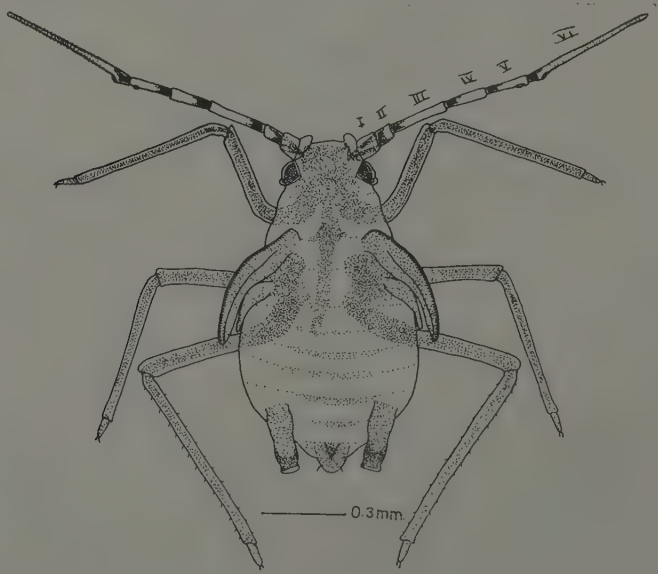

Fig. 10 : A wing-padded nymph which later gives rise to alate female.

possessing wing pads, which are known in aphid literature as the « pupae ».

This particular stage durates for about four days or sometimes for a longer period. During this time, the wing pads attain their full growth and are ready to give rise to the wings by which the insect takes to the air. Although the antennae of the pupa is six-segmented as in the adult alate, yet the individual segments have not attained their full growth. The secondary sensoria characteristic of the third and fourth antennal segments of the fully developed winged aphid, have not yet shown their appearance. Antennal and ocular tubercles are well pronounced. Wing pads are well developed and reach the second abdominal segment. Body is somewhat elongated and can thus be easily differentiated with the help of a simple magnifying lens from the ordinary fourth instar. The cauda is clearly differentiated but does not yet extend beyond the anal plate. The tips of the legs are slightly darker in colour as in the adult and possess the fine hairs along their whole length characteristic of the adult. The cornicles possess the usual constriction, the swollen darker distal end and the clear ornamentations. In the cleared specimens, two or three dorsal tubercles per segment can be seen.

Measurements (mean of ten specimen) : Antennal segments : I, 152 μ, gibbous nature quite clear; II, 84 μ, stout, barrel shaped; III, 240 μ, well developed, the longest segment of all the other; IV, 192 μ, slightly smaller than the preceeding one; V, 164 μ, nearly of the same length as IV, but with a primary sensorium near its union with the following one; VI, basal part, 86 μ, small, with a sensorium at its junction with the filamentous part; ungus, 528 μ, very well developed with constrictions; whole antenea, 1446 μ, longer than body; body (from tip of head to tip of cauda), 1360 μ, shorter than body; cornicle, 256 μ, with darker and swollen distal end, ornamentations clear; tibia of hind leg, 736 μ, long, provided with hairs, slightly darker at its distal end; cauda, 78 μ, attained considerable growth, conical hinder part with a blunt end; proboscis, 832 μ, reaches beyond the second body segment; wing pads, 434 μ, reaches the second abdominal segment.

VIII. BIONOMICS

The dissemination of the banana bunchy-top disease is directly dependant upon and related to its only known vector, the aphid *Pentalonia nigronervosa* Coq. The habits, nature and biology of this aphid are all virgin problems that have not yet been tackled so far in a satisfactory way. Magee (1927) was the first and main worker, if not the only one, to discuss these points. He was able to detect that the rate of activity of aphids is affected by several factors among which temperature and humidity rank first.

In the course of the present work, no detailed regular experiments regarding the study of these important factors and their effect on the biology of the aphid, were conducted for the lack of controlled temperature and humi-

dity chambers. Detailed experiments on the biology and ecology of the aphid are planned for future work and will be carried on as soon as the controlled temperature — humidity cabinets are made available. However, continuous observations for two successive years in the field, greenhouse and in the laboratory on colonies bred in these different places on *Musa* trees, made it possible to know the following facts :

(1) That this aphid overwinters as apterous adult females. No egg-stage of this aphid was encountered here. This very fact makes it natural to expect no males during the life-history of this aphid; being thus a completely parthenogenetic one.

(2) That during summer months, the season of high temperature and comparatively low humidity, the aphids live under the leaf bases or in the unfurled leaves protected from these unfavourable conditions.

(3) That the aphid flourished best at temperatures ranging between 20-22° C. and a humidity of 60-70 %. Under such conditions, the aphids leave the leaf bases on the pseudostem and invade the top of the trees particularly the bases of the petioles and the heart leaves.

(4) In the rainy months of the winter (December and January), where the temperature and humidity reach the optimum, all trees examined during field excursions, were found infested with aphids. Very few insects were still seen to live on the leaf bases of the pseudostem. Very small suckers (peepers), just emerged from the soil, were also infested.

(5) Most of the dissemination of the virus is performed after the rainy winter months following the appearance of the alate aphid forms as a result of the favourable climatic factors.

(6) During the spring (late in March, and April), as the temperature rises and the relative humidity decreases, the aphids become less active, leave the top of the trees, and invade again the leaf bases to be protected through the months of drought. Few winged individuals were seen during this season. At moderate temperatures of 22-24° C. and relatively high humidity ranging from 58-65 %, the activity of the aphid is still considerable. Under such conditions, the small trees were still aphid-infested while the adult trees were almost aphid-free. This phenomenon can be explained by the fact that the mature trees are higher and hence more exposed to unfavourable conditions.

(7) The summer months (May, June, and July), where the temperature rises up to 30-33° C. and the relative humidity reaches its minimum ranging between 45-55 %, represent the most undesirable and unfavourable season in which the aphid is least active. Under these conditions, the aphids are found completely hidden under the leaf bases of the pseudostem or inside the unfurled central leaves. They usually live under the bases of the first whirl of leaves, not very far from the soil and even for several inches under the soil

surface where the relative humidity is greater near the watered soil. In these months, winged members that secure dissemination of the virus infections that appear in the fields in the months of September and October are detected in banana fields.

IX. FEEDING HABITS

During the study of the biology of this aphid, it was noticed that the insect usually prefers the middle youngest leaf, being the most delicate. Aphids are usually seen feeding in large colonies on the middle unfurled leaf or gathering along the whole length of the mid-rib with a tendency to colonise at its base. Although the two surfaces of the banana leaf are attacked by aphids, yet the lower surface, being more protected, is usually more preferred than the upper one.

During the unfavourable season of the year, aphids move from the top of the tree to the pseudostem where they infest the base of the first whirl of leaves.

In feeding, the aphid usually invades the superficial bundles, in spite of the considerable length of its stylets. This fact explains the extreme agile nature of the aphid finding it easy to withdraw its shallow inserted rostrum when slightly disturbed.

The feeding mechanism of many aphid species, as well as the route followed by their stylets through the host plant tissues, has been satisfactorily studied by previous authors. However, for the aphid *Pentalonia nigronervosa* Coq, very little work was done. The first study of this nature was carried by Ocfemia and others (1947) who tried to determine the way followed by the stylets of the insect through the leaves of the manila hemp (*Musa textilis*). As a result of their investigations, they concluded that the insect inserts the stylets either through the stomata or directly through the epidermis, piercing the leaf tissues, either intercellularly or intracellularly on their way to the phloem elements.

In the present investigation, aphid colonies on *Musa cavendishii* Lamb. were killed in site of feeding by exposure to chloroform vapours. The infested plant tissue is then fixed in F. A. A. fixative (a mixture of formalin, acetic acid and ethyl alcohol), then dehydrated as usual. Paraffin sections cut at a thickness of 14 μ were stained in safranin light green stain.

In the sections studied, the stylets were seen penetrating the epidermal cells. In some cases, they were found passing through the stomata. The course of the insect stylets, indicated by that of the stylet sheath, is from the surface proceeding intercellularly between the tissue cells to reach the phloem elements (Fig. 11). Although the majority of stylet sheaths were seen ending in the phloem region, yet in some cases the sheaths ended in the xylem elements, fiber cells or in the ordinary parenchyma. These locations

are supposed to be the hit and miss tracks tried by the insect in the process of searching for the right site of its food.

The insect, known as a phloem feeder, causes a considrable mechanical and physiological destruction to the plant tissues and especially the phloem. The inoculum, being introduced within the phloem elements, is easily translocated to the various parts and thus the virus has a wonderful opportunity to

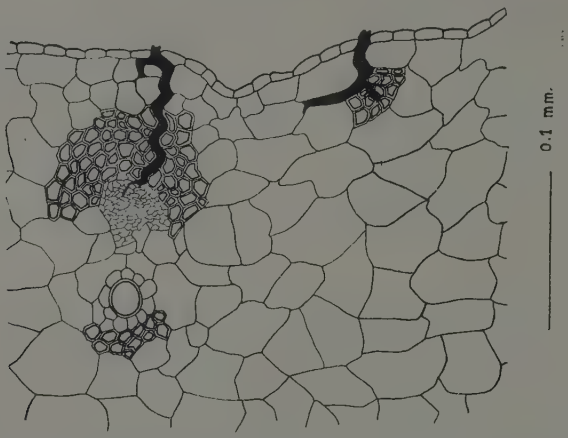

Fig. 11 : Diagram showing the reconstructed stylet sheath of the aphid vector with its tip on left ending in the phloem elements and on the right in the parenchyma and tracheids.

spread all over the plant tissues in a comparatively short period of time. Infection results in a disturbance of the translocation system in the plant due mostly probably to disorganization in the phloem elements.

The role of this aphid in transmission and dissemination of the banana bunchy-top virus will appear in a separate publication later on.

X. SUMMARY

The life-history of the banana aphid, *Pentalonia nigronervosa* Coq., the vector of the banana bunchy-top virus in Egypt was investigated. The morphology of adult apterous and alate viviparous females of this aphid is discussed. A study of the morphological characteristics of each of its nymphal stages is also presented. Measurements of body structures that are important in classification have been recorded. Differences between such structures at different nymphal stages are quite obvious. This indicates that the developmental stages of this aphid can be properly differentiated from each other and from similar stages of other aphid species on bases of variations in their morphological features.

Observations on the biology of this aphid have been made. Results of this study indicate that :

(1) The wet winter months with moderate degrees of temperature are the most favourable for the development of this aphid. It is also during this period that the aphid performs its maximal activities. Summer months, however, represent the unfavourable season for this apid. Temperatures between 20 to 22° C and relative humidity between 60 to 70 % were found to be the optimums for this insect.

(2) In winter, aphids were found in large masses colonising on the heart leaf and on the top of the plants. During the dry months of summer and autumn, aphids hide under the base of the first whirl on the pseudostem or in the heart leaves, seaking the more humid places.

(3) Most of the winged individuals appear during the wet favourable months of the year.

(4) This aphid species is very agile; the whole colony moves quickly on the slightest disturbance.

(5) In feeding, this aphid favours the superficial bundles with a preference of the phloem.

In the histological sections prepared in the present study, the majority of stylet sheathes, indicating the insect's feeding tracks, were found ending in that tissue. This fact adds to the efficiency of this aphid in transmission of the bunchy-top virus of bananas. For reaching the vascular bundles, the stylets pass intercellularly through the outer parenchymatous layers penetrating the epidermis either through the stomata or directly through its cells.

XI. ACKNOWLEDGMENTS

The authors wish to express their gratitude to Prof. Dr. M. Kamal, head of the Entomology Department, Faculty of Science (Alexandria), for his help, encouragement, and advice during the course of this work. Thanks are also due to Prof. Kamal for reading and correcting the manuscript.

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RESULTS OF THE ARMSTRONG COLLEGE EXPEDITION
TO SIWA OASIS (LIBYAN DESERT), 1935,
UNDER THE LEADERSHIP OF PROF. J. OMER-COOPER

Dytiscidae

[Coleoptera]

(with 2 Tables)

by Joseph Omer-Cooper,
Rhodes University, South Africa.

INTRODUCTION

Terrestrial animals are of necessity exposed to great hardships in deserts. Relatively few animals have successfully colonised arid regions, and there are for the most part very migratory types. Travelling long distances they have colonised wide areas in a relatively short time, and have much confused the historic picture of the colonization of the Oases. It is even fashionable to speak of an Eremian Region as if it were a geographical rather than an oecological entity. We can make little progress in our study of the history of Libyan biology unless we can overcome this difficulty.

The Libyan Oases, resulting as they do from the presence of springs which take their source from deep subterranean waters, offer an aquatic habitat which can have changed little since the Oases first appeared. Aquatic organisms do not suffer from changes in humidity, the chief difficulty of life on land, and as many of the springs are thermal the changes in temperature to which they are subjected are no greater than they would be in well watered temperate zones. Aquatic animals must therefore be considered with particular care in any attempt to reconstruct the historical zoo-geography of a desert country.

The Dytiscidae are of particular importance to us in this respect as they have been collected and recorded by a number of entomologists for almost two hundred years, and it is in consequence possible to discover a good deal about their distribution. These records have been looked up as carefully as has been possible under the conditions of isolation existing in South Africa. This has been considered necessary because much zoogeographical information is based on slender evidence and localities or distributions are usually given without quoting authority or giving any indication of the

period in which the observation was made. As has previously been shown, Omer-Cooper, Perkins and Tottenham 1928, the fauna of relatively undisturbed regions has been changing in a most astonishing manner during the last one hundred years, and it is most probable that the world is now in a process of cataclysmic change such has not occurred since the close of the Permian period. If this be correct it is clearly essential that before making pronouncements on distribution the old records should be considered with the utmost care. It has also been pointed out, Omer-Cooper and Rawson 1934, that peculiarities in distribution which appear to be the result of œcological conditions may be the result of the geographical history of the locality. Only by a careful study of the actual records was it possible to show this. There is yet a third reason for quoting authority, and giving the names of collectors when possible. The illiterate utilitarianism of the physical sciences is abhorrent to educated biologists. It is also a shocking thing to take the results of other men's labours without making due acknowledgement. The names of the collectors and students who laboured to accumulate the facts we use should be treasured in our memories ; some endured great hardships, others gave their lives, for the benefit of posterity and it is a poor spirited, ungenerous posterity that forgets their existence. An effort has therefore been made to avoid this depravity, and the bibliography has been annotated and made as full as possible in the hope that it may serve as a guide to the useful and pleasing study of the literature of the Libyan Dytiscidae.

TABLE I

Localities

NAME OF SPECIMENS	LOCALITIES AND NUMBER OF SPECIMENS										
	Siwa	Koreishid	Zeitoun	Khamissa	Maragi	Girba	Gara	El Arig	Bahareln	Sitra	TOTAL
1. *Laccophilus variegatus* (Germar)	3	—	—	—	—	—	—	—	—	—	3
2. *Hydrovatus cuspidatus* (Kunze)	22	1	—	24	—	6	—	15	35	—	102
3. *Bidessus signatellus* (Klug)	905	—	10	14	32	—	14	6	1	—	982
4. *Hygrotus inscriptus* Sharp	36	—	—	—	4	—	—	—	—	—	40
5. *Hygrotus (Coelambus) confluens* F	4	—	—	—	—	—	2	—	—	—	6
6. *Herophydrus guineensis* (Aubé)	66	—	—	85	52	—	3	—	—	—	206
7. *Hydroporus brucki* Wehncke	—	—	—	—	—	—	—	10	5	—	15
8. *Deronectes ceresyi* Aubé	136	3	—	—	49	1	12	2	3	1	207
9. *Agabus conspersus* (Marsham)	—	—	—	—	—	—	—	—	71	—	71
10. *Rantus pulverosus* (Stephens)	—	1	—	3	—	1	—	1	37	5	48
11. *Colymbetes fuscus* (Linnaeus)	3	—	—	—	—	—	—	—	—	—	3
12. *Eretes sticticus* (Linnaeus)	3	—	—	—	4	1	—	—	—	—	8
13. *Cybister vulneratus* Klug	12	—	—	1	1	1	—	—	—	—	15
14. *Cybister lateralimarginalis* (de Geer)	—	—	—	—	—	—	—	—	1	—	1
15. *Hydaticus ponticus* Sharp	—	2	—	—	—	—	—	—	9	—	11

TABLE II
Distribution

REGIONS	SPECIES															TOTAL SPECIES
	Laccophilus variegatus (Germar)	*Hydrovatus cuspidatus* (Kunze)	*Bidessus signatellus* (Klug)	*Hygrotus inscriptus* Sharp	*Hygrotus (Coelambus) confluens* Fabricius	*Herophydrus guineensis* (Aubé)	*Hydroporus brucki* Wehncke	*Deronectes ceresyi* Aubé	*Agabus conspersus* (Marsham)	*Rantus pulverosus* (Stephens)	*Colymbetes fuscus* (Linnaeus)	*Eretes sticticus* (Linnaeus)	*Cybister vulneratus* Klug	*Cybister lateralimarginalis* (de Geer)	*Hydaticus ponticus* Sharp	
Europe (North)					+				+	+	+			+		5
Europe (South)	+	+	+	+	+	+	+	+	+	+	+	+	+	+		14
North Africa	+	+	+		+	+		+	+	+	+	+	+	+		12
Asia (Western)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	15
Egypt	+	+	+		+	+		+		+		+	+	+		10
Africa (Ethiopic)			+			+						+	+			4
Asia	+		+						+	+	+	+		+	+	8
Aceania										+		+				2
America												+				1

These Tables show clearly that the fauna of the oases is not relict. The number of species obtained is surprisingly small, and these are not at all uniformly distributed. A large proportion of the species have a very wide range, and the majority are widely distributed. There seems no reason to doubt that they are an immigrant population which have reached the Oases from Asia Minor and North Africa.

There is no indication of an ancient Ethiopic element. The very few species which do occur in Ethiopic Africa are widely diffused species in Europe, Asia and North Africa.

This makes the mystery, which has intrigued me since I was first confronted by it in Tunisia in 1925, still deeper. Why have the Ethiopian insects strayed on the southward side of the Sahara ? They are extremely numerous. Ethiopic Africa is one of the richest collecting grounds in the world. In Ethiopia the species are often widely distributed. They are enured to hardship and they are experienced travellers, yet they stay behind the Sahara. What migration does take place appears to be in the opposite direction. Siwa is Mediterranean, not Ethiopic. It has no relict fauna.

and shows no indication at all that it has ever differed much from what it is today.

Of the fifteen specimens collected, four occurred in one oasis only. This is unexpected, for during the pluvial periods, if they ever much affected this region of the desert, it would be supposed that all the species would have moved freely from one oasis to another in the small area we are considering. Each of these species therefore deserves separate consideration.

Laccophilus variegatus Germar is a widely distributed insect, which ranges from the south of England to Persia, and from Morocco to Egypt. It is usually found in running water, where there is a good deal of water weed. We found it in one small stream only. It may have been a disappearing species at Siwa but, on the other hand, it may quite well have been a recent arrival. The fauna of Siwa itself is undoubtedly on the decline owing to anti-malaria campaigns and the introduction of *Tilapia* (a fish), but these things have not affected the majority of the other oases we visited. We did not find *L. variegatus* in any of these.

Agabus conspersus (Marsham) was taken in considerable numbers. The specimens varied very little amongst themselves, far less than one would have expected. They were however very different from the typical insect which I have taken on a good many occasions. For ten years at least before going to Siwa, I had never failed to recognise this species in the net, and was proud of the fact, as my wife, a much more experienced collector than myself, on more than one occasion, failed to do so. The specimens from Baharein were so different in colouring and general appearance in the net, that I did not connect them in any way with *A. conspersus ;* indeed it has taken the combined assurance of Mr. J. Balfour Browne, Dr. F. Guignot and my wife to convince me, that they really do belong to this species. It appears highly probable that such a uniform colony of a distinct and unusual variety is the progeny of a single fertile female, which was a chance immigrant from afar.

Colymbetes fuscus (L.). Although only three specimens were captured and the insect appeared to be confined to a few springs at Siwa, it was not so scarce as the number of captures suggest. It was not very difficult to see specimens, but their capture was not easy. The collecting net has a handle approximately six feet long. The average depth of the springs is rather more than twenty feet. The beetles keep well below the surface as a rule, and are wary, and dive downwards when disturbed. This species is a very common insect in Europe. It is easily recognised, and my wife and I collecting together for a god many years, have taken several hundred if not thousands. The specimens I saw at Siwa were narrower and very much darker than any I had ever seen before, and I did not recognise them in the water, in the net or even when pinned, as being *C. fuscus*. This

colony, I imagine, like the *A. conspersus* colony at Baharein consisted of the descendants of a single immigrant female.

Cybister lateralimarginalis (De Geer). Only a single female of this splendid species was collected, and it was taken in an environment so inimical that it was moribund when taken from the water. A full account of the capture is given in the Systematic List. There seems reason to believe that it was a recently arrived immigrant. Had conditions been favourable, a family might well have been established by this one individual.

It is interesting to notice that although the majority of the species of water beetles found in the Oases are not black, there is a tendency for the individuals to be somewhat darker than normal. This was very noticeable in the three species mentioned above, and dark individuals were also noticed amongst the specimens of *Hydrovatus cuspidatus* (Kunze) and *Deronectes ceresyi* Aubé. The melanism of the terrestrial fauna of the desert is unexpected and most interesting. That very brilliant young entomologist Withycombe, when I returned from Tunisia in 1925, much excited by the high degree of melanism I had noted there, showed me his material of melanic Hemiptera-Homoptera. He, had he believed, been successful in inducing the insects for some considerable time to a hot dry atmosphere. The induced melanism was inherited, and the inheritance appeared to be mendelian, as was clearly indicated by the collection he showed me. Unfortunately he died within a few months and left the work unfinished. It is possible that although water beetles are protected from most ultra-violet light, and are not normally subject to desiccation or unduly high temperatures, that heat and desiccation may in fact be the cause of the melanism observed in the Siwa Dytiscidae. These insects are immigrants or the descendants of immigrants, which almost certainly must have suffered severely while seeking for water. This may well have induced a physiological change so deep seated and intense, that it induced a heritable melanism.

Variation amongst the population appears to be no more and no less than would be expected under the varied conditions of salinity found in the waters of the oases. It is impracticable to make comparisons between this small fauna of widely distributed and normally rather variable species, and the much larger and less widely distributed fauna of the Abyssinian highlands.

One curious fact of general interest has appeared in making a detailed study of the distribution of the species. Two out of the fifteen species are insects which in the eighteenth century were not uncommon in the north of Europe, and extended as far north as Finland, and are now unknown in the more northerly parts of Europe, and very scarce except in the south. This is surprising. The earth appears to be getting warmer and drier. Africa and Asia are both suffering from increasing desiccation over wide

areas. A northward migration would therefore be expected to take place amongst water animals. To discover what is happening, a careful study of the early literature is essential. If this is made, I believe it will be found, that these are not isolated instances, but that there is a wide spread retreat from the North in progress.

Laccophilus variegatus (Germar)

Dytiscus variegatus Germar 1812.
Laccophilus variegatus « Knoch » Dejean 1821, p. 19, 1833, p. 56; Villa 1833, p. 7; Sturm 1834, pp. 125-126, tab. CXCVIII, fig. A.
Laccophilus variegatus (Germar), Aubé 1836, pp. 216-217, pl. 25, fig. 4; Aubé 1838, pp. 439-440; Heer 1839, p. 157; Rosenhauer 1842, p. 35; Hochhuth 1846, p. 221; Rosenhauer 1847, p. 82; Schaum *in* White 1847, p. 29; Gaubil 1849, p. 46; Fairmaire et Laboulbene 1854, p. 195; Rosenhauer 1856, p. 49; Redenbacher 1858, p. 93; Schaum and Kiesenwetter 1868, p. 81; Bedel 1881, p. 282; Sharp 1882, pp. 309-310; Preudhomme de Borre 1886, p. 20; Fowler 1887, p. 162, pl. 24, fig. 5; Seidlitz 1887, p. 79; Favre 1890, p. 50; Regimbart 1895, p. 133, Bertolini 1899, p. 22; Reitter 1908, p. 219, tab. 36, fig. 7; Khunt 1912, p. 142, fig. 101; Kuthy 1918, p. 43; Guignot 1933; pp. 505, 510-512; Falkenstrom 1939, p. 7; Balfour Browne 1940, pp. 181-182, Map. 34.

Localities. — Siwa: No. 12, Ilrhabit Reseur, 11th May, 3 spp.

Distribution. — Africa : Egypt, Guignot; Algeria, coll. Henon *teste* Regimbart; Morocco, Guignot. — Europe : England, Fowler, Balfour Browne; Belgium, Preudhomme de Borre; Germany, Aubé, Schaum, Reitter, Seidlitz; Switzerland, Favre; France, Aubé, Gaubil, Dejean, Bedel, etc.; Austria, Redtenbacher; Hungary, Kuthy: Spain, Aubé, Rosenhauer, Falkenstrom: Corsica, Sharp, Guignot; Italy, Schaum and White; Dalmatia, Dejean; Balkans, Guignot. — Asia : Asia Minor, Guignot; Syria, Guignot; Lencoran, Hochhuth; Transcausica and Persia, Zaitzev *teste* Guignot.

Remarks. — This species has its centre of distribution in the Mediterranean region, and is widely distributed in Europe, North Africa and Asia Minor. Owing to the introduction of *Tilapia* and the anti-malaria activities which had been going on for some years, suitable habitats for this species, which may well at one time have been abundant, were practically non-existant in 1935, and it is probable that the species will soon become extinct in the Siwa district.

Hydrovatus cuspidatus (Kunze) 1818

Hyphydrus cuspidatus Kunze, 1818, p. 68.
Hydroporus cuspidatus (Germar), Dejean 1821, p. 20; 1833, p. 58; 1837, p. 65.
Hydroporus cuspidatus (Kunze), Nicolai 1822, p. 32; Aubé 1836, pp. 361-362, pl. 41, fig. 5; 1838, pp. 477-479; Schaum *in* White 1847, p. 32; Rosenhauer 1847, p. 82; Gaubil 1849, p. 48; Gehin 1852, p. 17; Marcott 1852, p. 17; Fairmaire et Laboulbene 1854, p. 197; Rosenhauer 1856, p. 49.
Oxynoptilis cuspidatus (Germar), Schaum 1864, p. 106; Schaum and Kiesenwetter 1868, p. 29.
Non *Oxynoptilis cuspidatus* (Kunze), Blackburn 1875, p. 43.

Hydrovatus cuspidatus (Kunze). Bedel 1881, pp. 258-259; Sharp 1882, pp. 321-322.
Oxynoptilis cuspidatus (Kunze), Seidlitz 1887, p. 36.
Hydrovatus cuspidatus (Kunze), Régimbart 1895, p. 99; Reitter 1908, p. 207, Taf. fig. 1.
Oxynoptilus cuspidatus (Kunze), Kuhnt, 1912, p. 132, fig. 29; Petri 1912, p. 43; Kuthy 1918, p. 42.
Hydrovatus cuspidatus (Kunze), Guignot, 1933, pp. 278-280, figs. 136, 138-140.

Localities. — Siwa : No. 12, Ilrhabit Reseur, 11th May, 12 spp.; No. 19, Ilrhabit Uncorde, 18th May, 9 spp.; Khamissa : No. 53, Marsh, 22nd June, 24 spp.; Girba: No. 59, 12th August, 6 spp.; Koreishid: No. 55, 29th August, 1 sp.; El Arig: No. 48, West Spring, 7th June, 15 spp.; Baharein: No. 50, Spring in West Marsh, 10th June, 35 spp.

Distribution. — Africa : Egypte, Schaum; Lower Egypt, *coll.* Letourneux *teste* Bedel; Tunisia *coll.* Sedillot *teste* Regimbart; Algeria, Schaum, *coll.* Pic *teste* Guignot, Regimbart. — Europe : Belgium, Sharp; Germany, Aubé, Gaubil, Dejean, Sharp, Reitter, Kuhnt, Guignot; Austria, Guignot; Hungary, Kuthy, Guignot; France, Aubé, Gaubil, Gehin, Marcott *coll.* Thiebezard et Picard *teste* Fairmaire; Spain, Rosenhauer, Guignot ; Balearic Is., Guignot; Corsica, Sharp, Seidlitz; Sardinia, Sharp, Seidlitz; Italy, Aubé, Dejain, Sharp, Guignot; Dalmatia, Sharp, Guignot; Is. Zante, Hicker. — Asia : Palestine, Pic; Syria, *in coll.* Baudi *teste* Seidlitz.

Remarks. — A wide ranging species which probably originated in North Africa as its closest affinities appear to be with Ethiopic insects, although it is clearly not itself Ethiopic, but Mediterranean and European in distribution, and does not occur in Ethiopic Africa. It is in Europe, North Africa and Asia Minor, a not uncommon and widely distributed species.

Bidessus signatellus (Klug) 1834

Hydroporus signatellus Klug 1834.
Hydroporus thermallis Germar 1838, Tab. 3.
Hydroporus thermalis var. *tetragrammus* Hochhuth 1846, p. 223.
Hydroporus signatellus Klug, Apetz 1854, p. 13; Schaum 1864, p. 106; Gemminger et Harold 1868, p. 441.
Hydroporus thermalis Germ., Gemminger et Harold 1868, p. 441.
Hydroporus signatellus Klug, Régimbart 1877, p. 350.
Bidessus thermalis var. *signatellus* (Klug), Marseul 1882, p. 49.
Bidessus thermalis (Germ.), Sharp 1882, pp. 353-354.
Bidessus signatellus (Klug), Régimbart 1887, p. 636.
Bidessus thermalis var. *signatellus* (Klug), Seidlitz 1887; p. 48, Bertolini 1899, p. 21; Régimbart 1895, p. 85, 1899, p. 223; Ferrante 1909, p. 168; Pic 1910, p. 151; Scott 1912, p. 254; Peyerimhoff 1907, p. 9.
Hydroporus signatellus Klug, Andres 1914, p. 39.
Bidessus signatellus (Klug), Alfieri 1917, p. 94; Peschet 1917, pp. 8-10.
Bidessus thermalis var. *signatellus* (Klug), Zimmermann 1920, p. 58.
Bidessus signatellus var. *razzautii* Dodero 1922, p. 46.
Bidessus thermalis (Germ.), Omer-Cooper 1930, p. 253; Zimmermann 1930, p. 48.
Bidessus signatellus (Klug), Omer-Cooper 1931, pp. 769-770.
Guignotus signatellus (Klug), Guignot 1945, p. 245.

Localities. — Siwa : No. 2, Saline pool, 22nd April, 2 spp.; No. 3, Ain Brazee, 22nd April, 36 spp.; No. 4, Irrigation Pool of Ain Hammam, 25th April, 8 spp.; 5, Stream of Ain Raliet, 28th April, 410 spp.; No. 6, Redunkatil Tutnatee, 3rd March, 8 spp.; No. 9, Ultabu Hirfala, 10th May, 37 spp.; No. 10, Ultabu Teayda, 16th July, 40 spp.; No. 11, Irrigation Pool of Tannaklish, 10th May, 8 spp.; No. 13c, Hatiet Tanati water from garden, 26th July, 6 spp.; No. 14, Ultabu Tamrabat, 16th July, 19 spp.; No. 19, Ilrhabit Uncorde, 18th May, 10 spp.; No. 23, Ilrhabit Balee, 26th May, 7 spp.; No. 31, Ain Hammam, 9th July, 88 spp.; No. 33, Ain Harram, 9th July, 67 spp.; No. 43, Tagzerti, 12th July, 16 spp.; No. 46, Tut Narati, 4th August, 143 spp.; Siwa Depression: No. 18, Zeitoun, 24th August, 10 spp.; No. 44, Ain Jerie, 19th July, 14 spp.; No. 54, Irrigation Pool at Maragi, 24th June, 1 sp.; No. 61, Spring at Maragi, 26th August, 31 spp.; No. 59, Ain Girba, 12th August, 14 spp.; No. 48, El Arig, 7th June, 6 spp.; No. 50, Baharein, 10th June, 1 sp.

Distribution. — Africa : Egypt, Cairo, Ferrante; *coll.* Piochard de la Brûlerie *teste* Régimbart; Abou Zabal, Alfieri; Mazgouna, Ferrante; Kafr El Zayat, Ferrante; Maxama, Ferrante; Alexandria *coll.* Letourneux *teste* Régimbart; Rosetta, Pic; Fayoum, Pic; Sidi Gaber, Pic; Choubra, Pic; Tunisia: El-Hamma, Omer-Cooper, Mteurch, Omer-Cooper; Teboulbou, Omer-Cooper; Algeria, Hammeraia, *coll.* Sedillot *teste* Régimbart; Biskra, *coll.* Bedel *teste* Régimbart; Hammam Meskoutine, *coll.* Leprieur *teste* Régimbart; El-Kreider, Pic; Sénégal, *coll.* Mocquerys *teste* Régimbart; Sudan : Sennar, *coll.* Oscar and Alfred Brehm *teste* Apetz.; Dongola, Klug, Apetz; French Somaliland, Omer-Cooper; Abyssinia, Régimbart; Chagos Islands : Diego Garcia, Hugh Scott. — Europe : Belearic Islands, *coll.* Moragues *teste* Régimbart; Sicily, Seidlitz, *coll.* Ragusa *teste* Régimbart; Italy, Germar, Dodero; Dalmatia, Seidlitz; Greece, Klug; Lenkoran, Hochhuth, *coll.* Leider *teste* Régimbart. — Asia : Sinai, *coll.* Simon *teste* Régimbart; Arabia, Régimbart; Persia, Régimbart; India: Bengal *coll.* P. Cordon *teste* Régimbart.

Remarks. — This was by far the most abundant of the Dytiscidae at Siwa. It was almost the only Dytiscid in many of the larger springs and was particularly abundant close to the basin in the streams from the larger springs at Siwa. It is almost certainly a species of Mediterranean origin.

Hygrotus inscriptus Sharp

Hygrotus inscriptus Sharp 1882, pp. 404-405.

Localities. — Siwa : No. 4, Irrigation pool of Ain Hammam, April 5 spp.; No. 13c, Hatiet Tanati, 26th June, 4 spp.; No. 19, Ilrhabit Uncorde,

18th May, 8 spp.; No. 47, Anas Yutra, 6th May, 19 spp.; No. 54, Irrigation pool at Maragi, 24th June, 4 spp.

Distribution.— Persia and Mesopotamia, *coll.* C. Millingan *teste* Sharp.

Remarks.—I am indebted to J. Balfour Browne for the identification of this species. He very kindly compared the material from Siwa with Sharp's type in the British Museum. The species is evidently of a deserticolous habit and is so far known only from Persia, Mesopotamia and the Siwa Depression.

Hygrotus (Coelambus) confluens (Fabricius) 1787

Dytiscus confluens Fabricius 1787, p. 193; Gmellin 1790, p. 51; Fabricius 1792; p. 198; Paykull 1798, pp. 230-231; Fabricius 1802, p. 270; Marsham 1802, p. 424; Duftschmidt 1805, pp. 277-278.

Hyphydrus confluens (Fabr.), Gyllenhal 1808, p. 522; Schonherr 1808, p. 30; Leach 1817, p. 71; Zetterstedt 1828, pp. 233-234.

Hydroporus confluens (Fabr.), Nicolai 1822, p. 32.

Hygrotus confluens (Fabr.), Stephens 1828, p. 47; 1829, p. 44.

Hydroporus confluens (Fabr.), Sturm 1835, pp. 32-33; Aubé 1836, pp. 357-358, pl. 41, fig. 2; 1838, pp. 557-558; Erichson 1839, pp. 168-169; Heer 1839, p. 154.

Hygrotus confluens (Fabr.), Stephens 1839, p. 65.

Hydroporus confluens (Fabr.), Schiœdte 1841, pp. 451-452; Rosenhauer 1842, p. 35; Gaubil 1849, p. 48; Gehin, 1852, p. 8; Marcott 1852, p. 104; Murray 1853, p. 21; Wollaston 1854, pp. 87-88; Fairmaire et Laboulbène 1854, p. 213; Rosenhauer 1856, p. 49; Redtenbacher 1858, p. 88; Wollaston 1857, p. 27; 1865, p. 64, appendix p. 84; Schaum and Kiesenwetter 1868, p. 33; Blackburn 1875, p. 45; Régimbart 1877, p. 349.

Coelambus confluens (Fabr.), Bedel 1881, p. 233; Sharp 1882, p. 408; van der Branden 1884, p. 39; Preudhomme de Borre 1886, p. 20; Fowler 1887, pp. 168-169; Seidlitz 1887, p. 44; Oliveira 1893, p. 69; Régimbart 1895, p. 36; Barth 1896, p. 13; Bertolini 1899, p. 21; Bedel 1900, p. 61; Meinert 1901, pp. 365-368, Taf. 2, figs. 29 and 30; Cameron and Gatto 1907, p. 390; Reitter 1908, p. 208, Taf. 33, fig. 8; Pic 1910, p. 151; Day 1912, p. 202, Khunt 1912, p. 133, fig. 34; Balfour Browne 1912, p. 8.

Hydroporus confluens (Fabr.), Andres 1914, p. 40.

Coelambus confluens (Fabr.), Alfieri 1917, p. 94; Zimmermann 1921, p. 40 (87); Falkenstrom 1922, p. 32; Barrington 1927, p. 179; Omer-Cooper 1930, p. 253; Kinel 1934, p. 202; Guignot 1933, pp. 294-295.

Hygrotus (Coelambus) confluens (Fabr.), Balfour Browne 1934a, p. 150; 1934b, p. 242; 1940, pp. 210-211, Map.

Coelambus confluens (Fabr.), Ladeiro 1949, p. 5.

Localities.— Siwa : No. 42, Tarterad Hamid Bakour, 18th July, 2 spp.; No. 46, Tut Narati, 4th August, 1 sp.; No. obliterated, 20th August, 1 sp.; Gara, 3rd July, 2 spp.

Distribution. — Africa : Egypt, Aubé, Bedel, Zimmermann; Abou Zaabal, Alfieri; Helouan, Ferrante; Rosetta, Ferrante; Ramleh, *coll.* Schneider *teste* Andres; Tripolitania, Bedel, *coll.* Quedenfeldt *teste* Régimbart; Tunisia, Bedel, Omer-Cooper, *coll.* Sicard *teste* Régimbart; Algeria, Bedel, *coll.* Hénon, Leprieur, Martin, Oberthur *teste* Régimbart; Azores, *coll.* Barrois *teste* Régimbart ; Madeira, *coll.* Rousset *teste* Wollaston ; Canary Is., Wol-

laston, Sharp. — Europe: Lapland, Rosenhauer; Finland, Paykull; Sweden, Fabricius, Rosenhauer, Paykull, Gyllenhal; Denmark, Schiodte, Meinert; Scotland, Murray, Fowler, Balfour Browne; England, Marsham, Stephens, Blackburn, Day, Barrington, Balfour Browne; Ireland, Fowler, Balfour Browne; Germany, Schaum, Seidlitz, Khunt; Poland, Kinel; Switzerland, Heer; Chekoslovakia, Petri; Austria, Redtenbacher; Belgium, Preudhomme de Borre; France, Aubé, Gaubil, Gehin, Marcott, Guignot; Spain, Rosenhauer; Portugal, Oliveira; Malta, Cameron and Gatto; Italy, Bertolini; Sardinia, Bertolini. — Asia : Sinai Peninsula, *coll.* Kneucker and Guyot *teste* Zimmermann; Syria, Bedel, Pic, *coll.* Piochard de la Brûlerie *teste* Régimbart.

Remarks. — This insect appears to be one of a number of species of animals which are disappearing from the North of Europe. Amongst water animals this gradual withdrawal is very noticeable in the European Water-Tortoise. This once extended to Wicken Fen in Cambridgeshire, England. It is probable that when careful studies of the literature of the distribution of insects and other organisms are made, and the old literature is thoroughly explored, that this retreat from the North will be found to be of a common occurrence. *H. confluens* was first described by Fabricius from Swedish material and although recorded by Paykull from « Uplandia », by Rosenhauer in Lapland, and by Gyllenhall from Sweden it does not seem to have been taken in Scadinavia for many years. In Scotland also there were old records but none of very recent date, and despite a good deal of hard collecting in the North of England, it does not seem to have been taken there since it was caught by Britten in Cumberland as recorded by Day in 1912. We can find no recent records of any captures of this insect in northern Europe, and it appears to be rapidly becoming an insect of Mediterranean distribution.

Hydroporus brucki Wehncke 1875

Hydroporus brucki Wehncke 1875, p. 234; Sharp 1882, p. 464.
Hydroporus confusus var. Régimbart 1895, p. 27.
Hydroporus brucki Wehncke, Zimmermann 1919, pp. 171. 176; 1920, p. 82.

Localities. — No. 48, El-Arig, 7th June, 10 spp.; No. 50, Baharein, 10th June, 5 spp.

Distribution. — Europe : Greece, Régimbart; Russia : Crimea, Wehncke; Turkey, Régimbart. — Asia : Cyprus, Régimbart.

Remarks. — J. Balfour Browne who identified my specimens by comparison with the material in the British Museum (Natural History) writes: « *The Hydroporus*.... agrees perfectly with the « type » specimen of *brucki* Wehn. of Sharp. This specimen is labelled by Sharp « ind. auth. » so there is no grounds to doubt that your material is that species. It is certainly not *confusus* which is much more closely and finely punctured.

Régimbart had regarded *brucki* as a variety of *confusus* Lucas. This is not so, at least on the basis of the authentic specimens utilized by Sharp. *H. brucki* is much closer to *limbatus* Aubé, and is, I think, probably the eastern representative of that western Mediterranean species ». The species probably has its centre of distribution in Asia Minor and is not widely distributed. The Asiatic water-beetles are unfortunately not well known and there is little doubt that when this region is properly studied, the known range of this species and of *Hygrotus inscriptus* will be considerably increased. These two species are the only Dytiscidae collected which have a rather circumscribed range and both are Asiatic. This range in the Libyan desert also appears to be limited, and they are not recorded for more than a small area : *H. brucki* occurs only in two small oases while *H. inscriptus* is found only at Siwa and Maragi (which is in the Siwa Depression and only a few miles from Siwa). These species therefore seem to owe their presence to chance immigration. In each case their presence could well be accounted for by the immigration of a single fertile female. There is certainly nothing whatsoever to suggest that they are remnants of an indigenous fauna.

Herophydrus guineensis (Aubé) 1838

Hyphydrus guineensis Aubé 1838, pp. 455-456.
Hydroporus turgidus Erichson 1843, p. 220.
Hyphydrus barbarus Schaum and White 1847, p. 34.
Hyphydrus ferrugineus Lucas 1849, p. 98, taf. 11, fig. 5.
Hyphydrus guineensis Aubé, Gehin 1852, p. 16.
Hydroporus turgidus Erich., Schaum 1864, p. 106.
Hydroporus hyphydroides Perris 1864, p. 277; Marseul 1871, p. 106.
Hydroporus turgidus Erich., Régimbart 1877. p. 349.
Hyphydrus guineensis Aubé, Sharp 1882, p. 393.
Herophydrus guineensis (Aubé), Ragusa 1882, p. 248.
Hygrotus guineensis (Aubé), Seidlitz 1887, p. 38; Régimbart 1895, pp. 87-88; Barthe 1896, p. 13.
Herophydrus guineensis (Aubé), Bertolini 1899, p. 21.
Hyphydrus guineensis (Aubé), Gahan 1903, p. 265.
Herophydrus guineensis (Aubé), Régimbart 1906, p. 237; Ferrante 1909, p. 167; Pic 1910, p. 151; Régimbart 1910, p. 3.
Hydroporus turgidus Erich., Andres, 1914, p. 40.
Herophydrus guineensis (Aubé), Alfieri 1917, p. 94; Peschet 1922, p. 374; 1925, p. 35; Zimmermann 1926, p. 29; Omer-Cooper 1931, p. 780; Gochwendtner 1932, p. 36.

Localities. — Siwa : No. 4, Irrigation pool of Ain Hammam, 25th April, 11 spp.; No. 6, Redunkatil Tutnatee, 3rd May, 1 sp.; No. 11, Irrigation pool of Tannaklish, 10th May, 4 spp.; No. 12, Ilrhabit Reseur, 11th May, 20 spp., 25th August, 8 spp.; No. 19, Ilrhabit Uncorde, 18th May, 16 spp.; No. 33, Ain Harram, 9th August, 6 spp.; Siwa Depression : No. 53, Khamissa Marsh 22nd June, 85 spp.; No. 54, Irrigation pool at Maragi, 24th June, 6 spp.; No. 61, Spring at Maragi, 26th August, 46 spp.; Gara : No. 56, Ain Shifa, 2nd July, 3 spp.

Distribution. — Africa : Egypt, Schaum, Sharp, Seidlitz; Cairo, *coll.* E. Simon *teste* Régimbart; Ferrante; Abou Zaabal, Alfieri; Ramleh, *coll.* Letourneux *teste* Régimbart; *coll.* Schneider *teste* Andres, Pic; Algeria, Lucas; *coll.* Leprieur, Hénon *teste* Régimbart; Sokotra *coll.* Balfour *teste* Sharp, Gahan; Abyssinia, *coll.* Raffray *teste* Régimbart; Omer-Cooper; Sénegal, Aubé, Gehin, *coll.* Nodier *teste* Régimbart; Guinea, Aubé; Congo, *coll.* Tschoffen *teste* Régimbart; Kenya, *coll.* Alluaud *teste* Régimbart, *coll.* Patrizi *teste* Peschet; Tanganyika, *coll.* Mettiner *teste* Zimmermann; Angola-Rhodesia Frontier, Peschet. — Europe : Corsica, Sharp, Seidlitz. — Asia : Arabia, Sharp, Seidlitz, Régimbart.

Remarks. — This insect belongs to an Ethiopic genus of which a few species have established themselves in the Mediterranean region and Asia Minor. It is no doubt an Ethiopic species which has migrated into Europe and North Africa in comparitively recent times. It is clearly a wandering species as it is found in Sokotra, Arabia and Corsica as well as in North Africa and East and West Ethiopic Africa.

Deronectes ceresyi (Aubé) 1836

Hydroporus ceresyi Aubé 1836, pp. 260-261, pl. 30, fig. 2; 1838, pp. 543-544.
Hydroporus salinus Joly 1840, p. 42, pl. 3, fig. 7; Gaubil 1849, p. 48.
Hydroporus ceresyi Aubé, Gaubil 1849, p. 47.
Hydroporus cerisyi Aubé, Gehin 1852, p. 18; Fairmaire et Laboulbene 1854, p. 212.
Hydroporus ceresyi Aubé, Rosenhauer 1856, p. 49.
Hydroporus lyelli Wollaston 1856, p. 26.
Hydroporus ceresyi Aubé, Wollaston 1864a, p. 78; Schaum 1864, p. 106.
Hydroporus baeticus Schaum 1864b, p. 109.
Hydroporus ceresyi Aubé, Wollaston 1867, p. 66.
Hydroporus acuminatellus Fairmaire 1876, p. 49.
Hydroporus undecimlineellus Fairmaire 1876, p. 141.
Hydroporus ceresyi Aubé, Régimbart 1877, p. 351.
Deronectes baeticus (Schaum), Sharp 1882, p. 433.
Deronectes ceresyi (Aubé), Sharp 1882, p. 434.
Hydroporus undecimlinellus Fairm., Sharp 1882, p. 813.
Hydroporus acuminatellus Fairm., *baeticus* Schaum, Sharp 1882, p. 995.
Deronectes cerisyi (Aubé), van den Branden 1884, p. 46.
Deronectes ceresyi (Aubé), Seidlitz 1887, p. 54.
Hydroporus cerisyi (Aubé), Oliveira 1893, p. 71; Régimbart 1895, pp. 19-20.
Hydroporus (*Deronectes*) *ceresyi* Aubé, Barte 1896, p. 14; Bertolini 1899, p. 21.
Hydroporus (*Deronectes*) *cerisyi* Aubé, Bedel 1900, p. 58.
Deronectes ceresyi (Aubé), Cameron and Gatto 1907, p. 390.
Hydroporus (*Deronectes*) *cerisyi* Aubé, Zaitzev 1908, p. 118.
Deronectes (*Potamodytes*) *ceresyi* (Aubé), Zimmermann 1919, p. 187; 1920, p. 123.
Potamonectes cerisyi (Aubé), Zimmermann 1921, p. 41 (85).
Deronectes ceresyi (Aubé), Omer-Cooper 1930, p. 254.
Potamonectes ceresyi (Aubé), Guignot 1933. pp. 468-469.
Deronectes ceresyi (Aubé), Balfour Browne, 1934, p. 242.

Localities. — Siwa : No. 2, Saline Pool, 22nd April, 11 spp.; No. 4, Irrigation Pool of Ain Hammam, 25th April, 1 sp.; No. 13, Birket Aghourmi, very saline pool, 3rd May, 39 spp., 26th June, 19 spp.; No. 19, Irhabit Un-

corde, 18th May, 26 spp.; No. 21, Drainage pool of Torrubea, 21st May, 4 spp.; Siwa Depression : No. 55, Koreishid, 30th June, 1 sp., 29th August, 2 spp.; No. 61, Maragi, 26th August, 49 spp.; Gara : No. 56, Ain Shifa, 2nd July, 12 spp.; Girba : No. 59, Ain Girba, 12th August, 1 sp.; El Arig, No. 48, 7th June, 2 spp.; Baharein, No. 50, 13th June, 3 spp.; Sitra, No. 51, 16th June, 1 sp.

Distribution. — Africa : Egypt, *coll.* de Ceresy *teste* Aubé, Cairo, Schaum; Alexandria, *coll.* Simon *teste* Régimbart; Tripolitania, Guignot; Tunisia, Bedel, Omer-Cooper; Pantelleria, Régimbart; Algeria, *coll.* Martin, Olivier, Bedel, Desbrochers des Loges *teste* Régimbart; Madeira, Wollaston; Canary Is., Wollaston, caught in the sea by Alluaud *teste* Régimbart. — Europe: Portugal, Régimbart; *coll.* Vloxem *teste,* Oliveira; Spain, Schaum, Rosenhauer, Régimbat; South of France, Aubé, Joly, Gaubil, Gehin, Guignot; Corsica, Guignot; Italy, Aubé; Sardinia, Aubé; Malta, Cameron and Gatto; Greece, Guignot; Russia: Crimea, *coll.* Seminov *teste* Guignot. — Asia: Sinai, *coll.* Kneucker and Guyot *teste* Zimmermann; Palestine, *coll.* Piochard de la Brûlerie *teste* Régimbart.

Remarks. — Our material consists of specimens which are rather dark and correspond closely to the coloured figure given by Aubé. The specimens we have collected in Tunisia are very much lighter, the ground colour being light yellow rather than testaceous. It is this lighter coloured insect which appears to have been described by Joly, and the Egyptian *D. cerisyi* and the Mediterranean *D. salinus* differ considerably in colouring. This is of considerable interest as it forms an example of the tendency for desert animals to become dark. The species is typically Mediterranean and it frequents brackish and saline waters.

Agabus conspersus (Marsham) 1802

Dytiscus conspersus Marsham 1802, p. 427.
Dytiscus conspersus Nicolai 1822, p. 31.
Colymbetes subnebulosus Stephens 1828, p. 72; 1829, p. 50
Colymbetes conspersus (Marsh.), Stephens 1828, pp. 72-73, pl. XII, fig. 4; 1829, p. 50.
Agabus subnebulosus (Steph.), Aubé, 1836, pp. 157-158, pl. 19, fig. 2; 1838, pp. 329-330.
Colymbetes subnebulosus Stephens 1839, p. 74.
Colymbetes conspersus (Marsh.), Stephens 1839, p. 74.
Agabus conspersus (Marsh.), Schaum and White 1847, p. 23; Gehin 1852, p. 13; Murray 1853, p. 17; Fairmaire et Laboulbène 1854, p. 189; Schaum and Kiesenwetter 1868, pp. 109-110; Bedel 1881, p. 273; Sharp 1882, pp. 512-515.
Agabus gougeleti Reiche (1863), Sharp 1882, p. 753.
Agabus conspersus (Marsh.), de Borre 1886, p. 21; Fowler 1887, p. 194, pl. 28, fig 7; Seidlitz 1887, p. 94; Ellis 1889, p. 201; Regimbart 1895, p. 155; Barthe 1896, p. 15; Bertolini 1899, p. 22; Régimbart 1899, p. 275; Bedel 1900, p. 64; Fowler and Donnisthorpe 1907, p. 213; Reitter 1908, p. 222, pl. 37, fig. 13; F. Balfour Browne 1912, p. 8; Kuhnt 1912, p. 144, fig. 112; Barrington 1927, p. 180; Omer-Cooper 1930, p. 254; Guignot 1933, pp. 563, 570-571; F. Balfour Browne 1950, pp. 115-119.

Locality. — No. 50, Baharein, 10th-13th June, 71 spp.

Distribution. — Africa: Tripolitania, *coll.* Alluaud *teste* Bedel; Tunisia, *coll.* Sedillot and Mayet *teste* Régimbart and Bedel, Omer-Cooper; Algeria, *coll.* Merkl *teste* Régimbart, Sharp, Bedel; Morocco, Bedel, Régimbart; Tangiers, *coll.* Fairer *teste* Régimbart; Azores, Sharp; Canary Islands, Bedel. — Europe, « toute l'Europe », Aubé, « Corfu bis Schweden », Seidlitz; England, Marsham, *coll.* F.W. Hope *teste* Stephens, White, Sharp, Fowler, Ellis, Barrington, Balfour Browne; Denmark, Sharp, Schaum; Germany, Schaum, Nicolai, Reitter, Kuhnt; Belgium, Preudhomme de Borre ; France, Gehin, Bedel, Guignot; Spain, Sharp; Balearic Islands, *coll.* La Fuente *teste* Guignot; Corsica, Sharp, Barthe, *coll.* du Buysson *teste* Guignot; Greece, Schaum. — Asia: Turkey, Schaum; Transcaucasus, Sharp, Guignot; Syria, Guignot; N. India, *coll.* R. Oberthur *teste* Régimbart.

Remarks. — The seventy-one specimens captured were all alike, and were rather small and slightly more ovoid in form than any specimens of *A. conspersus* (Marsh.) I have collected in Tunisia or in England. They were also much darker, appearing black in the net, but when immersed in alcohol, as is often the case, seeming lighter in colour with the elytra dark brown and the pronotum black. These insects after some years in alcohol have become a little lighter in colour, and now although still very dark approximate more to the colour of *A. conspersus*. Their uniformity and extreme colour variation suggest that they are the offspring of a single female, which changed to find its way into this tiny oasis. It is possible that exposure to heat and drought induces heritable melanism, and that this insect lost in the desert, and only succeeding in discovering water after long exposure and great hardships, produced melanic offspring. Whatever the cause may be it is certain that the *A. conspersus* of Baharein are a race showing great uniformity, and at the same time a striking degree of melanism together with other minor characters separating them from the North African members of the species. They have been examined by J. Balfour Browne and Dr. Guignot who agree that there can be no doubt that they belong to the species *A. conspersus* Marsh.

Rantus pulverosus (Stephens) 1828

Non *Dytiscus notatus* Fabricius, 1781, p. 296.
Non *Dytiscus punctatus* Furcroy 1785, p. 70, *teste* Güignot 1942, p. 87.
Non *Dytiscus conspersus* Marsham 1802, p. 427.
Dytiscus notatus Dejean 1802, p. 4.
Non *Dytiscus conspersus* Gyllenhal 1808, pp. 482-483, *teste* F. Balfour Browne 1935, p. 223.
Colymbetes notatus Dejean 1821, p. 19.
Colymbetes pulverosus (Knoch), Stephens 1828, pp. 69-70, pl. XII, fig. 2; Stephens 1829, p. 49.
Colymbetes notatus (Fab.), Villa 1833, p. 7.
Rantus notatus (Fab.), Dejean 1833, p. 54.
Colymbetes pulverosus (Steph.), Sturm 1834, pp. 78-79, tab. CXCIV; Audouin et Brullé 1835, p. 217.

Colymbetes conspersus (Gyll.), Aubé 1836, pp. 104-105, pl. 13, fig. 3; Aubé, 1838, pp. 237-238.
Rantus pulverosus (Knoch), Hope 1838, p. 131; Stephens 1839, p. 71.
Colymbetes pulverosus Steph., Erichson 1839, pp. 150-151; Heer 1841, p. 145.
Colymbetes conspersus (Gyll.), Schiodte 1841, p. 496.
Colymbetes pulverosus Steph., Rosenhaur 1842, p. 32; Schaum *in* White 1847, p. 16.
Colymbetes conspersus (Gyll.), Gaubil 1849, p. 44.
Colymbetes pulverosus Gehin 1852, p. 12.
Colymbetes conspersus (Gyll.), Murray 1853, p. 16.
Colymbetes pulverosus (Sturm), Fairmaire et Laboulbene 1854, p. 185.
Colymbetes pulverosus (Steph.), Redtenbacher 1855, p. 94; Rosenhauer 1856, p. 48; Schaum 1864, p. 105; Schaum and Kiesenwetter 1868, p. 85.
Rantus pulverosus (Sturm), Hochhuth 1871, p. 236.
Colymbetes pulverosus (Steph.), Sharp 1873, p. 48; Fairmaire 1875, p. 481.
Rhantus punctatus (Fourcroy), Bedel 1881, p. 276.
Rhantus annectens Sharp 1882, p. 608.
Rhantus pulverosus (Steph.), Sharp 1882, p. 609; Preudhomme de Borre 1886, p. 22; Fowler 1887, p. 202, pl. 29, fig. 13.
Rantus conspersus (Gyll.), Seidlitz 1887, pp. 101-102.
Colymbetes pulverosus (Steph.), Ellis 1889, p. 200; Favre 1890, p. 47; Oliveira 1893, p. 73.
Rhantus punctatus (Fourcroy), Régimbart 1895, pp. 179-180.
Rantus conspersus (Gyll.), Barthe 1896, p. 15.
Rhantus punctatus (Fourcroy), Régimbart 1899, p. 306; Alluaud 1900, p. 67; Bedel 1900, p. 65.
Rhantus pulverosus (Steph.), Fowler and Donnisthorpe 1907, p. 214.
Rhantus punctatus (Geoff.), Reitter 1908, p. 227, taf. 33, fig. 3; Kuhnt 1912, p. 147, figs. 135-137.
Colymbetes pulverosus Andres 1914, p. 41.
Rhantus pulverosus (Steph.), Zimmermann 1920, pp. 204-205; Zimmermann 1921, p. 42 (89); Falkenstrom 1922, p. 27.
Rhantus punctatus (Geoffr.), Barrington 1927, p. 180.
Rhantus pulverosus (Steph.), Bertrand 1928, pp. 137-138, pl. XXXII; Omer-Cooper and Tottenham 1932, p. 508.
Rhantus punctatus (Fourcroy), Guignot 1933, pp. 625-628.
Rhantus pulverosus (Steph.), Feng 1934, p. 117.
Rhantus pulverosus (Steph.), F. Balfour Browne 1935, pp. 223-226.
Rhantus punctatus (Fourcroy), Zimmermann and Geschwendtner 1936, pp. 3-5.
Rhantus pulverosus (Steph.), F. Balfour Browne 1940, pp. 200 and 205.
Rhantus pulverosus (Steph.) ssp. *bramardi* Guignot 1942, p. 87.
Rhantus annectens (Sharp), J. Balfour Browne 1945, p. 113.
Rhantus pulverosus (Steph.), F. Balfour Browne 1950, pp. 228-232, Map 30.

Localities. — Siwa Depression: No. 44, Ain Jerie, Khamissa, 19th July, 3 spp.; No. 55, Koreishid, 29th August, 1 sp.: Girba: No. 59, Ain Girba, 1 sp.; El Arig: No. 48, West Spring, 7th June, 1 sp.; Baharein: No. 50, Spring in West Marshes, 10-13 June, 37 spp.; Sitra: No. 51, Spring at edge of Lake, 16th June, 5 spp.

Distribution. — Africa: Cairo, *coll.* Simon *teste* Régimbart; Alexandria, *coll.* Letourneux *teste* Régimbart, *coll* Schneider *teste* Andres; Lower Egypt, Bedel; Tunisia, *coll.* Abdoul-Kerim *teste* Bedel; Algeria, Sharp, Bedel; Madagascar, *coll.* Sikora *teste* Alluaud; Azores, *coll.* Barrois *teste* Régimbart. — Europe: Sweden to Spain, Schaum; all Europe, Aubé; Europe except Finland and Scandinavia, Zimmermann; South and Central Europe: Sweden, Dejean, Falkenstrom; Scotland, *coll.* Little *teste* Murray; Belgium, Preud-

homme de Borre: England, Stephens, Fowler, White, Barrington, Balfour Browne, Ellis; France, Bedel, Bertrand, Gaubil, Guignot; Germany, Reitter, Schaum; Switzerland, Favre; Austria, Redtenbacher; Russia, Hochhuth. — Asia: Sinai Peninsula, *coll.* Knuecker and Guyot *teste* Zimmermann; Mesopotamia, Sharp; India, *coll.* Breteaudeau *teste* Régimbart; Assam, Sharp; Birma, *coll.* Leonardo Fea *teste* Régimbart; China, Régimbart, Feng; Japan, *coll.* Faurie et Ferrie *teste* Régimbart, Sharp; Java, Sharp; Australia and Oceania: Australia, Sharp, Aubé; New Zealand, Sharp; ?Samoa, Sharp; New Caledonia, Sharp; New Hebrides, Fiji, etc., Balfour Browne.

Remarks. — This widely ranged species which is common in the far East, particularly in China, and which is also common in Australia and New Zealand, and seems to be represented in the Pacific by a sub-species, *R. annectens* Sharp, has never been recorded from Ethiopic Africa. It is probable that *R. annectens* Sharp is a sub-species of *R. pulverosus* Steph. with which it has been identified by Zimmermann. F. Balfour Browne's discovery that Gyllenhals species was based on specimens of another insect to that described by Stephens as *pulverosus,* made it uncertain that *R. pulverosus* actually occurred as far North as Sweden, but it now seems that it does reach that country, as it has been found there by Falkenstrom. It is a species which belongs rather to middle Europe and Asia than to the Mediterranean, where it does not appear to be at all numerous. It is however certainly of a very wandering disposition, so that it is not surprising that it should occur in the Libyan Oases.

Colymbetes fuscus (Linnaeus) 1758

Dytiscus fuscus Linnaeus 1758, p. 411; Geoffroy 1762, pp. 185-186; Gmelin 1788, p. 1946; Fabricius 1792, pp. 189-190; Cederhjelm 1798, p. 31; Paykull 1798, pp. 203-204; Fabricius 1801, pp. 261-262.

Dytiscus striatus Linn., Marsham 1804, p. 414.

Dytiscus fuscus Linn., Duftschmidt 1808, pp. 255-256; Gyllenhal 1808, pp. 477-478; Schonherr 1808, p. 15; Dejean 1821, p. 19; Nicolai 1822, p. 31; Zetterstedt 1828, pp. 209-210.

Colymbetes striatus (Linn.), Samouelle 1819, p. 158;; Stephens 1828, pp. 68-69; 1829, p. 49.

Colymbetes fuscus (Linn.), Stephens 1828, p. 69; 1829, p. 49; Villa 1833, p. 7.

Colymbetes striatus (Linn.), Wilson and Duncan 1834, pp. 125-126.

Cymatopterus fuscus Dejean 1833, p. 54; 1837, p. 61.

Dytiscus fuscus (Gyll.), Sahlberg 1834, p. 156.

Colymbetes fuscus (Linn.), Wilson and Duncan 1834, p. 126; Sturm 1834, pp. 73-75.

Colymbetes striatus (Linn.), Brullé 1835, pp. 216-217; Aubé 1836, pp. 97-98, pl. 12, fig. 3; Aubé 1838, pp. 225-227; Hope 1838, p. 131.

Non *Colymbetes fuscus* (Linn.), Aubé 1836, pp. 100-101, pl. 12, fig. 5; 1838, pp. 228-229.

Colymbetes fuscus (Linn.), Hope 1838, p. 131; Rosenhaur 1842, p. 32; Heer 1838, p. 144; Erichson 1839, p. 150; Schiodte 1841, p. 497; Gaubil 1849, p. 44; Rosenhauer 1856, p. 48; Redtenbacher 1858, p. 93.

Cymatopterus fuscus (Linn.), Gemminger et Harold 1868, p. 447.

Colymbetes fuscus (Linn.), Schaum and Kiesenwetter 1868, pp. 83-84; Sharp 1882, p. 629; Preudhomme de Borre 1886, p. 22; Fowler 1887, p. 203, pl. XXX., fig. 4.

Cymatopterus fuscus (Linn.), Seidlitz 1887, p. 103; Favre 1890, p. 47.
Colymbetes fuscus (Linn.), Oliveira 1893, p. 73; Régimbart 1895, p. 184.
Cymatopterus fuscus (Linn.), Barthe 1896, p. 15.
Colymbetes fuscus (Linn.), Bedel 1900, p. 65.
Cymatopterus fuscus (Linn.), Meinert 1901, pp. 381-382; Tab. III., figs. 68-72; Cameron and Gatto 1907, p. 390; Kuthy 1918, p. 44.
Colymbetes fuscus (Linn.), Reitter 1908, p. 229, Tab. 38, fig. 10; Kuhnt 1912, p. 149; F. Balfour Browne 1912, p. 9; Petri 1912, p. 48; Zimmermann 1920, pp. 210-211; 1921, p. 42 (89); Omer-Cooper 1930, p. 254; Omer-Cooper and Tottenham 1932, p. 508; Guignot 1933, pp. 649-653, figs. 449-454; Donnisthorpe 1939, p. 22; Ladeiro 1949, p. 9; F. Balfour Browne 1950, pp. 246-250.

Localities. — Siwa: No. 6, Redunkalil Tutnatee, 3rd May, 1 sp.; No. 19, Ilrhabit Uncorde, 18th July, 1 sp.; No. 23, Ilrhabit Balee, 26th May, 1 sp.

Distribution. — Africa: Tunisia: Tunis, *coll.* Elena *teste* Bedel; Tozeur, *coll.* Mayet *teste* Bedel; Degach, *coll.* Sedillot *teste* Bedel; Gabès, *coll.* Mayet *teste* Bedel; Kibili, coll. Normand *teste* Bedel; Algeria: Bone and La Calle, *coll.* Lucas *teste* Régimbart; Tebessa, *coll.* Sedillot *teste* Régimbart; Morocco: Casablanca, *coll.* Quedenfeldt *teste* Régimbart; Tangier, *coll.* Quedenfeldt *teste* Régimbart. — Europe: common in all parts of Europe except the extreme north, Guignot, Sharp. etc.; Lapland, Zetterstedt, Rosenhauer; Finland, Sahlberg; Malta, Cameron and Gatto; Corsica, Sharp; Crete, Sharp. — Asia: Sinai Peninsula (var. *semirufus* Zimm.), *coll.* A. Kneucker *teste* Zimmermann; Syria: Sharp, Régimbart; Smyrna: Sharp; Persia: Peschet, Guignot.

Remarks. — *Colymbetes fuscus* is a well known and abundant European insect which ranges from the Arctic Circle to the Mediterranean Region and Asia Minor. It is tolerant of a wide range of conditions and there are few types of aquatic habitat in which it is not to be found. In North Africa, Régimbart notes that it is darker than in Europe, and the specimens from Siwa are darker than any I have collected previously in Finland, England or Tunisia. They are also rather narrow and when in the net give an impression of being much elongated, so that one does not recognise them as *C. fuscus* (Linn.). J. Balfour Browne has very kindly compared them with the varied series in the British Museum and considers that they belong to this species. There can be no doubt that this insect is Palaearctic in its origin for it is common in the north of Europe, and belongs to a genus which is circumpolar in distribution and has not been recorded further south than Arabia.

Eretes sticticus (Linnaeus) 1767

Dytiscus sticticus Linnaeus 1767, p. 666; Fabricius 1775, p. 232; 1781, p. 294.
Dytiscus griseus Linn., Fabricius 1781, pp. 293-294; 1787, p. 190.
Dytiscus sticticus Fabricius 1787, p. 190; Gmelin 1788, p. 1947.

Dytiscus griseus Fabr., Gmelin 1788, p. 1947; Fabricius 1792, p. 191.
Dytiscus sticticus Linn., Fabricius 1792, p. 191; Olivier 1795, No. 40, p. 21, pl. 2, fig. 11; Fabricius 1801, p. 263.
Dystiscus griseus Feb., Olivier 1795, No. 40, p. 20, pl. 2, fig 12; Fabricius 1801, p. 263.
Dyticus sticticus Linn., Schonherr 1808, pp. 16-17.
Dyticus griseus Dejean 1821, p. 18.
Eunectes sticticus (Linn.), Erichson 1832, p. 23-24.
Eretes griseus (Fab.), Laporte de Castelnau 1833, p. 397.
Nogrus griseus (Fab.), Dejean 1833, p. 53.
Nogrus pallidus Eschscholtz, Dejean 1833, p. 53.
Eunectes sticticus (Linn.), Klug 1834, tab. XXXIII, fig. 2.
Eunectes helvolus Klug 1834, tab. XXXIII., fig. 3.
Eunectes succinctus Klug 1834, tab. XXXIII., fig. 4.
Eunectes sticticus (Linn.), Audouin et Brullé 1835, pp. 221-222.
Eunectes griseus (Fab.), Aubé 1836, pp. 74-75, pl. 10, fig. 1.
Nogrus griseus (Fab.), Dejean 1837, p. 61.
Eunectes punctatus Zubkoff 1837, p. 66, tab. IV., fig. 1.
Eunectes griseus (Fab.), Aubé 1838, pp. 124-126; Hope 1838, p. 117.
Eunectes sticticus (Linn.), Hope 1838, p. 117.
Eunectes plicipennis Motschoulsky 1845, p. 29.
Eunectes griseus (Fab.), Schaum *in* White 1847, p. 10.
Eunectes helvolus Klug, Schaum *in* White 1847, p. 10.
Eunectes succinctus Klug, Schaum *in* White 1947, p. 10.
Eunectes occidentalis n. sp. Schaum *in* White 1847, p. 10; Schaum *in* Erichson 1847, p. 73.
Eunectes helvolus Klug, Boheman 1848, pp. 236-237.
Eunectes griseus (Fabr.), Gaubil 1849, p. 44; Gehin 1852, p. 10.
Eunectes sticticus (Linn.), Apetz 1854, p. 12; Fairmaire et Laboulène, 1854, p. 182; Lacordaire et Chapuis 1854, pp. 429-430; Rosenhauer 1856, p. 48.
Eunectes griseus (Fab.), Redtenbacher 1858, p. 99.
Eunectes conicollis Wollaston 1861a, p. 90.
Eunectes subdiaphanus Wollaston 1861b, p. 100; 1864, p. 84; 1865, p. 70, App. pp. 11-84.
Eunectes subcoriaceus Wollaston 1861b, p. 99; 1865, p. 71, App. pp. 12 and 84; 1867, p. 35.
Eunectes occidentalis White, Chevrolat 1863, p. 202.
Eunectes helvolus Klug, Wollaston 1867. pp. 35-36, App. pp. 273-274.
Eunectes sticticus (Linn.), Redtenbacher 1868, p. 23.
Eunectes succinctus Klug, Walter 1871, p. 5.
Eunectes subcoriaceus Woll., Marseul 1871, p. 93.
Eunectes sticticus (Linn.), Régimbart 1877, p. 348; 1878, p. 457, pl. 10, fig. 6; Sharp 1882, pp. 699 and 913.
Eunectes helvolus Klug. Marseul 1882, p. 4.
Eretes sticticus (Linn.), Van der Branden 1884, pp. 108-109.
Eunectes sticticus (Linn.), Seidlitz 1887, p. 104.
Eretes sticticus (Linn.), Séverin 1890, p. CVCIII.; Gestro 1892, p. 9; Ganglebauer 1892, p. 506; Régimbart 1895a, pp. 208-209; 1895b, p. 192; Oliveira 1895, p. 76.
Eunectes sticticus (Linn.), Barthe 1896, p. 15.
Eretes sticticus (Linn.), Régimbart 1898, p. 155; 1899, p. 340-341; Bertolini 1899, p. 23; Alluaud 1900, p. 70; Bedel 1900, p. 66; Meinert 1901, pp. 400-402, Tab. V., figs. 123-130; Régimbart 1901, p. 334; 1906, p. 252; Csiki 1908, p. 503; Ferrante 1909, p. 171.
Eretes helvolus (Klug), Pic 1910, p. 149.
Eretes sticticus (Linn.), Scott 1912, p. 261; Peschet 1917, pp. 37-38; Zimmermann 1919, p. 77; 1920, pp. 216-217; Peschet 1920, p. 254; 1922, p. 375; Zimmermann 1926, p. 31; Omer-Cooper 1930, p. 254; Bertrand 1931a, pp. 294-295; 1931b, pp. 289-305; Omer-Cooper 1931, p. 794; Feng 1934, p. 121, pl. I, fig. 23, pl. II, figs. 7, 19, 37; Falkenstrom 1936, p. 235; J. Balfour Browne 1939, p. 485; Guignot 1941, pp. 18-19; 1943, p. 100; Blackwelder 1944, p. 79; Balfour Browne, J. 1945, pp. 107 and 114; 1946, p. 452; Brink 1946, p. 150; Guignot 1948, pp. 22-24; Leech 1948, pp. 415 and 462; Ladeiro 1949, p. 9; Guignot 1950, p. 262.

Localities. — Siwa : No. 21, drainage pond of the garden of Torrubea, 20th May, 3 ssp.; Girba: No. 59, 12th August, 1 sp.; Maragi: No. 61, 4 spp.

Distribution. — Africa : Egypt, Schaum, Pic, Ferrante; Cairo, *coll.* Piochard de la Brûlerie *teste* Régimbart; Tunisia, *coll.* Doria, Sedillot, Letourneux *teste* Bedel, Omer-Cooper; Algeria, White, Bedel; Azores, Régimbart; Madeira *coll.* Bewick *teste* Wollaston, Bedel; Canary Isles, Wollaston, Marseul, Bedel; Cape Verde Isles, *coll.* Gray *teste* Wollaston; « Sahara », Bertrand; Somaliland, *coll.* Brichetti-Robecchi *teste* Gestro; Abyssinia, Omer-Cooper; Gold-Coast, Régimbart; Sénégal, *coll.* Mocquerys, Nodier, *teste* Régimbart; Portugese Guinea, *coll.* Monard *teste* Guignot; Kenya, *coll.* Alluand *teste* Régimbart; Uganda, *coll.* Carpenter!; Tanganyika Territory, Zimmermann; Belgian Congo, *coll.* Damas *teste* Guignot; S.W. Africa, *coll.* Lind!: N. Rhodesia, *coll.* Lewin!; S. Rhodesia, *coll* Lovemore!, Omer-Cooper; Transvaal, *coll.* Hutchinson!, Omer-Cooper; Natal, *coll.* Omer-Cooper; Cape Province, *coll.* Power!, Omer-Cooper; Madagascar, *coll.* Perrot *teste* Alluand; Aldabra, *coll.* Abbot *teste* Alluand, *coll.* Fryer *teste* Scott; Mauritius *coll.* Carosin, Carie, *teste* Peschet. — Europe : France widely distributed, Dejean Gehin, Barthe, Fairmaire, Des Gozis, Guignot; Spain, Rosenhauer, Sharp; Portugal, Oliveira, Ladeiro; Italy, Bertolini; Corsica, Sharp; Sardinia, Sharp; Austria, Redtenbacher; Hungary, Csiki; Borders of the Black Sea, Guignot. — Asia : Sinai, Zimmermann, Ferrante; Arabia, Sharp; Mesopotamia, Sharp; Siberia, Sharp, Guignot; Transcaucasus, Guignot; Persia, Motschoulsky, Guignot; Turkestan, Zubkoff, Zimmermann; Himalaya, Régimbart; India, Gmelin, Fabricius, Dejean, Sharp, etc.; India Pondichery, *coll.* Maindron *teste* Régimbart; India Chota Nagpur, *coll.* Cardon *teste* Severin; Andaman Islands, Régimbart; Singapore, Redtenbacher; Siam, Sharp, Guignot; Indo-China, Régimbart; China (many localities), Feng, Falkenstrom; Manchuria, Brink, J. Balfour Browne; Japan, Sharp; Formosa, Sharp, Guignot; Indo-Malaya: Phillipine Islands, Sharp, Régimbart; Sumatra, Sharp, Régimbart; Penang, Sharp. — Oceania : Mariana Island, J. Balfour Browne. — United States of America : California, Leech; Lower California, Leech; Kansas, Leech; New Mexico, Leech; Texas, Leech; Tres Marais Islands, *coll.* Forrer *teste* Régimbart, Leech; Revillagigedo Islands, Leech! Clarion Island, *coll.* Keifer *teste* Leech; Mexico, Blackwelder, Sharp, Régimbart; West Indies, White, Sharp, Guignot; Leeward Islands, Blackwelder; Guadeloup, Blackwelder; Peru, Sharp, Guignot; Galapagos Islands, Sharp.

Remarks. — This species is remarkably variable, and in all the localities in which we have collected it in Africa, it shows considerable individual differences in size and colouration. It does not, we believe, usually form local races and it is probable that when these have been recorded the

number of speciments examined was small. Had long series been available the variable nature of the species would have become apparent. It frequents muddy and brackish waters, and rarely occurs in ponds with much vegetation. It is one of the most widely distributed of all animals, and does not appear to owe anything to human agency as do most widely spread land animals. If Willis is correct, this insect should be the most ancient species of the Dytiscidae now living.

Cybister vulneratus Klug 1834

Trochalus bivulnerus Dejean 1833, p. 53, *n.n.*
Cybister vulneratus Klug 1834, pl. XXXIII., fig. 1.
Cybister binotatus Klug 1835, p. 28.
Cybister bivulnerus Dejean 1837, p. 60; Aubé 1838, pp. 91-92.
Non *Cybister vulneratus* Mannerheim, Dejean 1837, p. 67.
Non *Gyretes vulneratus* Mannerheim, Aubé 1838, pp. 752-753.
Cybister madagascarensis Aubé 1838, pp. 94-96.
Cybister bivulnerus Aubé, Schaum *in* White 1847, p. 6.
Cybister vulneratus Klug, Schaum *in* White 1847, p. 6.
Non *Cybister binotatus* Boheman 1848, pp. 234-235.
Cybister bivulnerus Aubé, Gaubil 1849, p. 44; Gehin 1852, p. 9; Rosenhauer 1856, p. 47.
Cybister vulneratus Klug, Sharp 1882, p. 772.
Cybister binotatus Klug, Sharp 1882, pp. 721-722; Seidlitz 1887, p. 113; Régimbart 1895, pp. 223-224; Linell 1896, p. 703; Bertolini 1899, p. 23; Alluaud 1900, p. 70, pl. XXXIV, figs. 6, 7; Régimbart 1906, p. 292; Peschet, 1917, pp. 721-722; Zimmermann 1926, p. 31.
Cybister binotatus Klug, A. Petroff 1932, pp. 220-222.
Cybister (Melanectes) vulneratus Klug, Brink 1945, p. 12.

Localities. — Siwa: No. 10, Ultabu Teayda, 16th August, 4 spp.; No. 12, Illrhabit Reseur, 11th May, 1 sp.; No. 19, Illrhabit Uncorde, 29th June, 1 sp., 18th July 5 spp.; Khamissa: No. 53, Marsh, 22nd June, 1 sp., unnumbered, 7th September, 1 sp.; Maragi: No. 54, 24th June, 1 sp.; Girba: No. 59, 12th August, 1 sp.

Distribution. — Africa: Egypt, *coll.* Morgan, *coll.* Wilkinson *teste* White and Schaum, Gehin; Baharia Oases, *coll.* Alfieri *teste* Alfieri; Algeria, Régimbart, Peschet; Morocco, Régimbart, Peschet; Somaliland, Peschet; Zanzibar, Peschet; Nyassa, Peschet; Tana River, Linell; Tanganyika, Zimmermann; Sénégal, Aubé, Dejean, Régimbart, Peschet; W. Africa, *coll.* Doubleday *teste* White and Schaum; Sierra Leone, *coll.* Mocquerys *teste* Régimbart, Benin, Peschet; Congo, *coll.* Mocquerys *teste* Régimbart; Belgian Congo, *coll.* Overlaet, *teste* Geschwendter; Delagoa Bay, *coll.* Péringuey *teste* Régimbart; Madagascar, Aubé, *coll.* Goudot, Hildebrandt, Frey, Alluand *teste* Alluaud, Régimbart. — Europe: Mediterranean; Seidlitz; S. Europe, Sharp; Sicily, Sharp; Spain, *coll.* Rosenhauer *teste* Régimbart. — Asia: Arabia, Klug; Hedjaz, *coll.* Millingen *teste* Sharp.

Remarks. — This species is almost wholly black and is, therefore, an insect which is presumably adapted for desert life. Its wide range seems

to be a characteristic of most insects found in the waters of desert regions. It was the only common large water beetle of the Siwa Depression.

I can find no difference between *C. vulneratus* Klug and *C. binotatus* Klug. My material both from Siwa and from Ethiopic Africa shows considerable variation in shape and size.

C. vulneratus has precedence over *C. binotatus* and the fact that the *Cybister vulneratus* Mannerheim of the D e j e a n Catalogue of 1837 referred to a Gyrinid beetle of the genus *Gyretes* does not invalidate it, as *C. vulneratus* Mannerheim is a *nomen nudum* and also did not appear until three years after K l u g had published his beautiful figure and description. Why it has been treated as a variety of *C. binotatus* Klug instead of *vice-versa* I do not know.

Cybister lateralimarginalis (De Geer) 1774

Dytiscus laterali-marginalis De Geer 1774, p. 396.
Dytiscus roeseli Fuessly 1775, p. 18.
Dyticus virens Mueller 1776, p. 70.
Dytiscus glaber Bergstrasser 1778, p. 31, taf. 6.
Dytiscus roeseli Bergstrasser 1778, pp. 50-51, tafs. 7 and 8.
Dystiscus intricatus Schaller 1783, p. 311; Gmellin 1790, p. 1952.
Dytiscus virescens Gmellin 1790, p. 1958.
Dyticus dispar Rossi 1790, pp. 199-200.
Dytiscus roeseli Fabricius 1792, p. 259; Dejean 1802, p. 4; Duftschmid 1805, pp. 251-252; Schonherr 1808, p. 13.
Dytiscus roeselii Dejean 1822, p. 18.
Dytiscus dispar (Rossi), Nicolai 1822, p. 29.
Cybister roeselii (Fab.), Curtis 1827, pl. 151; Stephens 1828, p. 92; Stephens 1829, p. 53.
Trochalus roeselii Dejean 1833, p. 53.
Cybister roeselii Sturm 1834, pp. 62-66, tab. CXCII and CXCIII.
Cybister virens (Muell.), Audouin et Brullé 1835, pp. 222-223, pl. 9, fig. 4.
Cybister roeselii (Fab.), Aubé 1836, pp. 48-49, pl. 3, fig. 6.
Trochalus roeselii (Fabr.), Dejean 1837, p. 60.
Cybister roeselii (Fab.), Aubé 1838, pp. 66-67; Heer 1838, p. 41; Erichson 1839, p. 141; Stephens 1839, p. 78; Schiodte 1841, p. 528; Rosenhauer 1842, p. 30; Schaum *in* White 1844, p. 5.
Cybister chaudoirii Hochhuth 1846, pp. 213-214.
Cybister roeselii (Fab.), Rosenhauer 1847, p. 81; Gaubil 1849; p. 44.
Cybister lepedus Apetz 1852, p. 34, taf. 112.
Cybister roeselii (Fab.), Gehin 1852, p. 8; Fairmaire et Laboulbène 1854, pp. 180-181; Redtenbacher 1858, p. 98; Schaum 1864, p. 105.
Trogus virens (Muell.), Gemminger et Harold 1868, p. 460.
Cybister roeselii (Fab.), Schaum and Klesenwetter 1868, pp. 114-115; Hochhuth 1871, p. 241.
Cybister lateralimarginalis (De Geer), Bedel 1881, pp. 255-256 and 281.
Cybister ponticus Sharp 1882, p. 748.
Cybister roeselii Sharp 1882, p. 747; van der Branden 1884, pp. 113-114.
Cybister lateralimarginalis (De Geer), Seidlitz 1887, pp. 111-112.
Cybister virens (Muell.), Atkinson 1891, p. 150.
Dytiscus herberti Peytour 1894, p. 39.
Cybister roeselii (Fab.), Oliveira 1893, p. 75; Régimbart 1895, p. 209.
Cybister herberti (Peytour), Sharp 1896, p. 21.
Cybister lateralimarginalis (De Geer), Barthe 1896, p. 15; Bedel 1900, p. 66; Mueller 199, p. 119; Sahlberg 1900, p. 14; Reitter 1908, p. 234; taf. 40, fig. 4; Kuhnt 1912. p. 152, fig. 114; Petri 1912, p. 49; des Gozis 1912, p. 16; Sahlberg 1913, p. 46;

Deville 1914; p. 63; Kuthy 1918, p. 44; Zimmermann 1920, pp. 260-263; Abot 1928, pp. 62-63; Omer-Cooper 1930, p. 254; Guignot 1933, pp. 733-737.

Cybister lateralimarginalis De Geer (nec *laterimarginalis*), A. Petroff, 1932, pp. 220-222.

Cybister hedini Zaitziv, Falkenstrom 1933, p. 20; 1935, pp. 20-22.

Cybister lateralimarginalis De Geer (*nec laterimarginalis*), A. Petroff, 1932, 1941, p. 126; Goidanich 1943a, pp. 65-70; 1943b, pp. 1-12; Brink 1944, pp. 37-43; 1945, pp. 19-20; Ladeiro 1949, p. 10; F. Balfour Browne 1950, pp. 288-289.

Distribution. — Africa : Egypt, Aubé, *coll.* Alfieri *teste* Alfieri; Tunisia, *coll.* Elena *teste* Bedel, Omer-Cooper; Algeria, Régimbart, Bedel; Tangiers, Régimbart; Morocco, Bedel, Gschwendtner. — Europe : Sweden, De Geer, Schaller, Brink, etc.; Finland?, Sahlberg; Denmark, Müller, Gmellin, Meinert; Germany, Bergstrasser, Nicolai, Kuhnt, etc.; England, Curtis, Stephens, Schaum; Belgium, Preudhomme de Borre; France, Dejean, Rosenhauer, Fairmaire, etc.; Switzerland, Fuessly, Heer; Austria, Duftschmidt, Rosenhauer; Hungary, Kuthy; Portugal, Ladeiro, Sharp, Oliveira; Spain, Rosenhauer, Gautier; Italy, Rossi, Villa, Goidanich; Corsica, Deville, Sharp; Dalmatia, Müller; Yugo-Slavia, Apetz, Apfelbeck; Russia, Hochhuth. — Asia : Is. Mytilene, Sahlberg; Turkey, *coll.* Forbes *teste* Schaum; Syria, Bedel, Zimmermann; Iraq, *coll.* Millingen *teste* Sharp; Armenia, Guignot; Azerbaijan, *coll.* Baron de Gotsch *teste* Hochhuth; Persia, *coll.* Marquis Doria *teste* Sharp; Siberia, Sharp; Turkestan, Zaitziv, Brink; Afganistan, Gschwendtner, Brink; Kashmir, Brink; Mongolia, Falkenstrom, Gschwendner.

Remarks. — This magnificent insect was recorded from Egypt by Aubé, and much later by Petroff. We obtained but an single specimen, the only unique in our collection of Dytiscidae, and this was taken under most unusual circumstances.

In a small inlet of the lake, which is almost saturated with salt, fresh water running over the salt water produces an astonishing phenomenon described by Smith 1947, pp. 139-159. The fresh water, being of a much lower specific gravity than the salt water, prevents the usual thermal circulation and, acting as an insulator, allows the solar radiation to heat the deeper water to a higher temperature. We thought it was a thermal spring so hot was the water. The surface water had a temperature of 81°F. while at a depth of 2 ft. a maximum of 132°F.

While we were examining this strange place a small splash caused me to look to the right when I saw, not far away, a large *Cybister* swimming strongly near the surface. It seemed in perfect condition and had, I believe, alighted an instant before when the splash attracted my attention.

The mud was soft and very slippery so that I had small hope of collecting the specimen. Almost immediately it dived and disappeared from sight. Pursuit seemed to be out of the question. Soon, however, it again appeared at the surface swimming slowly. I struggled through the mud towards it. This frightened the beetle and it dived again. When it appeared at the

surface once more it was moribund, overcome by the great heat of the water into which it had plunged.

This cannot have been the normal habitat of the insect, and we found no suitable place anywhere. It is possible that we had the extraordinary good fortune to witness the arrival of an immigrant from afar. It is interesting to note that in the water we brought back from this birket Dr. K. Blackburn found the pollen of pine trees.

Like *Hygrotus* (*Coelambus*) *confluens* Fabr. this beetle is receding from the north.

Hydaticus ponticus Sharp 1882

Hydaticus ponticus Sharp 1882, p. 662; Marseul 1882, p. 117; Régimbart 1899, pp. 325-326; Guignot 1936, pp. 58-59.

Localities. — Siwa Depression : No. 55, Koreishid, 30th June, 2 spp.; Baharein: No. 50, 10-13th June, 9 spp.

Distribution. — Asia : Mesopotamia, Sharp; India, Sind, *coll.* F. Moore *teste* Régimbart.

Remarks. — This insect is easily confused with *H. leander* (Rossi), and can only be recognised with certainty by a study of the aedeagus. J. Balfour Browne has kindly compared our material with Sharp's type in the British Museum. It is not known from Ethiopic Africa.

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auf das Schuljahr Ostern 1853 bis dahin 1854. Als Einladungsschrift zu den vom 3. bis 7. April 1854 in der Aula des Josephinum stattfindenden Schulfeierlichkeiten von Schulrath D. Heinrich Eduard Foss Director. Bugefügt ist eine Abhandlung von Prof. J.H. Apetz: De Coleopteris, quae Oscarus et Alfredus Brehm in Africa legerunt. Altenburg [*The first part has pp. 1-20, and Apetz paper has a separate title page and pagination*]).

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A note on the biology of *Calidea duodecimpunctata* (Fabr.) in the Sudan

[Hemiptera-Heteroptera : Pentatomidae]

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INTRODUCTION

The distribution of the genus *Calidea* Laporte (Pentatomidae : Scutellerini) is limited to the Ethiopian Region, including Arabia and Madagascar. Freeman (1939) lists eleven species ; of these, five have been recorded from the Sudan, viz. : *C. bohemani* (Stäl), *C. distinguenda* (Reiche and Fairmaire), *C. dregii* Germar, *C. duodecimpunctata* (Fabr.), and *C. nana* (Hahn and Herrich-Schaffer).

None of these species can be regarded as of great economic importance in the Sudan, though some are minor pests of various agricultural and horticultural crops, including cotton. *C. nana* is occasionally a serious pest of « dukhn » (*Pennisetum typhoideum* Rich.) and « simsim » (*Sesamum orientale* L.) in Kordofan Province.

C. bohemani and *C. dregii* are two species with a wide African distribution and are well-known as pests of cotton, particularly in N. Rhodesia and Tanganyika. In the former country, *C. dregii* was found by Bebbington and Allen (1931) to be associated with the spread of internal boll-rot fungi. All the five species of *Calidea* occurring in the Sudan have been recorded from cotton in the Gezira area, or elsewhere, but none has so far been suspected of causing any damage or of acting as a vector of fungal disease.

C. duodecimpunctata occurs locally throughout the Gezira, usually in small numbers on cotton and a variety of other host plants. During July and August in the 1950-1951 season however, a heavy local outbreak of this species was observed on vegetables in the Wad Medani area and this note is the result of observations made during the above period.

TECHNIQUE

In order to determine the incubation period, and duration of the nymphal stages, insect material was kept in petri-dishes (6 cms. and 9 cms. diameter) at laboratory temperatures of 25 - 33°C. *Calidea* prooved easy to rear in captivity using « sorib » (*Phyllanthus niruri* L.) and « mulokhia » (*Corchorus olitorius* L.) as food plants for adults and nymphs. Rearing was also carried out on potted « sorib » plants in an insectary.

DISTRIBUTION

C. duodecimpunctata has been recorded only from the north-eastern and central regions of the Sudan. Its known distribution is bounded to the south by Singa and to the west by the White Nile. Localities from which it has been taken are listed below, first records only, being given.

Northern Province : Timerab, 12.iii.1919 (H. W. Bedford) ; Khor Hankanot, 14.ii.1928 (W.P.L. Cameron).

Kassala Province : Port Sudan, 3.x.1914 (H.H. King) ; Khor Gowity, 6.iii.1928 (W.P.L. Cameron) ; Khor Arbaat Delta, 3.v.1926 (H. B. Johnston) ; Khor Hambokeb, 9.ii.1928 (W. P. L. Cameron) ; Erkowit, 17.ii.1908 ; Kassala, iv.1917 (C.H. Tompson).

Nile Blue Province : Gezira Research Farm, Wad Medani, 28.vii.1923 (H. B. Johnston) ; Sennar Abu Geili, 14.vi.1925 (H. B. Johnston).

LIFE HISTORY AND HABITS

Oviposition

Oviposition is performed on the stem, petiole or leaf of the host plant, the eggs being deposited in groups. An examination of 12 such groups showed a range of 18 to 40 eggs per group with an average of 25. In the course of oviposition on a stem or petiole, the female moves slowly around depositing the eggs in a spiral pattern, each whorl in contact with the next. The egg is covered by a glutinous secretion which facilitates adhesion to the stem and to neighbouring eggs. Oviposition is accompanied by rapid dorso-ventral vibrations of the female's abdomen : these are rapid (approximately 300 per minute) but of small amplitude. They take place during, and persist for a short period after, egg-laying.

The Egg

The egg is spherical, 1 mm. in diameter, opaque white in colour, with the chorion finely and densely punctured. During incubation, the changes from white to yellow, then to pale orange and finally, by the time hatching is imminent, to deep orange.

The embryonic head lies at the anterior, exposed apex to the egg. Two red, oval eye-spots become apparent during incubation, also the dark brown cephalic denticle. This is a T-shaped sclerotized hatching spine lying on the vertex of the head with the stem of the « T » directed posteriorly over the anterior of the thorax. The eyes later become kidney-shaped, the concave side lying latered. Just prior to hatching, the segments and limbs can be clearly seen through the chorion.

A ring of small blunt white tubercles is visible encircling the apex of the egg and passing on the surface of the chorion to the outside of the eye-sports and cephalic denticle. They are slightly larger and more distantly spaced on the denticle side and vary in number from 17 to 24.

Small pulsations of the nearly mature embryo occur in an anterior-posterior plane as hatching approaches. At eclosion, a circular rupture occurs, in a plane slightly inclined to that of the row of turbercles, cutting off an apical operculum via which the first instar nymph makes its exit.

The incubation period varies from 2 to 4 days with an average of 2 1/2 days (77 specimens).

Habits of the Nymphs

The newly emerged nymphs cluster on the empty eggs for half to one hour then move onto the upper side of a leaf where they commence feeding. These first instar nymphs are highly gregarious and remain close together until the first moult. The second instar nymphs become more active and tend to disperse though they may still be found in small aggregations. This gregarious tendency decreases as moulting proceeds and stage V nymphs are usually found feeding singly. The nymphs will occasionally feign death upon disturbance. In common with certain other Hemiptera, they are capable of forcibly ejecting the faeces. Stage IV nymphs for example, can eject their orange-red faeces to a distance of about 1 cm.

Nymphal Instars

There are five nymphal instars requiring approximately 26 days for development from hatching to emergence of the adult. The following Table shows the duration of each instar, in days, with the range and average. Moulting of all individuals from the same clutch of eggs is practically simultaneous to give the second instar. The moulting of later instars becomes more variable and shows a greater range in time.

The period from egg-laying to adult emergence thus varies from 23 to 38 days, with an average of 28.5 days.

The nymphs of all instars are orange-red in colour immediately after ecdysis. In the first instar nymph, this colour tends to persist although

the head, appendages, thorax, and abdominal tergites III-VI darken to a light brown shortly after eclosion. In instars II-V, sclerotization is more extensive and involves all tergites and sternites giving dark metallic blue-black and green nymphs. Immediately prior to moulting, instars II-IV are

	INSTAR NUMBER					TOTAL NYMPHAL PERIOD
	I	II	III	IV	V	
Range	2 - 2.5	3	3 - 4.5	2.5 - 8	10 5 - 16	21 - 34
Average	2.25	3	3.9	4 4	12.5	26
Number of specimens	64	3	5	15	15	—

of approximately the same size as the next succeeding instar (III-V). They can however be distinguished by the orange lateral regions of the abdomen and the smaller size of the tergites, these features being indicative of the approach of ecdysis.

Average lengths of the various instars, in millimetres, are : I (1.3) ; II (1.8) ; III (2.6) ; IV (4.0) ; V (5.8).

The Adult

A conspicuous metallic green and blue-black insect with the scutellum extending beyond, and completely covering, the abdomen. Taxonomic features of this and other species of *Calidea* are given by Freeman (1939). The adult flies cumbersomely, but only in hot sunny weather ; during rain it clings tenaciously to the undersides of leaves or petioles, or to the stems of host plants. The adult feeds on foliage, and in the case of cotton, on the bolls, but no obvious signs of damage can be ascribed to it.

HOST PLANTS

The host plants on which *C. duodecimpunctata* has been taken are listed below (« A » represents adults, « N » nymphs, and « E » eggs).

Polygale erioptera DC. (Polygalaceae), A,N; *Phyllanthus niruri* L. (Euphorbiaceae), A,N,E; *Solanum dubium* Fresen (Solanaceae), A; *Lycopersicum esculentum* Mill. (Solanaceae), E ; *Helianthus annuus* L. (Compositae), A; *Corchorus olitorius* L. (Tiliaceae), A,N,E; *Allium cepa* L. (Liliaceae), E; *Heliotropium* sp. (Boraginaceae), A; *Gossypium barbadense* (Malvaceae), A; *Abutilon pannosum* (Forst. f.) Schlecht (Malvaceae), A ; *Medicago sativa* L. (Leguminosae), A; *Panicum turgidum* Forsk. (Graminae), A; *Daucus carota* L. (Umbelliferae), E.

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A contribution to the host-selection-principle as applied to *Bruchus (Callosobruchus) maculatus* F.

[Coleoptera: Bruchidae]

(with 2 Tables)

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INTRODUCTION

The host-selection principle is one of the most interesting principles that have recently received much of the attention of entomologists. It is not only of importance from the standpoint of applied entomology, but also because it might suggest a method by which biological races as well as new species of insects may have come into existence.

In 1917, Hopkins gave the following definition of the principle: «an insect species which breeds in two or more hosts, will prefer to continue to breed in the host to which it has become adapted». It follows then, that the continued isolated breeding of this polyphagous insect species in each of its hosts for a long series of generations, will give rise to a number of differentiated biological races, or varieties, each in turn being monophagous and restricted to the particular host in which it has been bred.

It seems that the above definition of Hopkins was put forward without of Walsh's work published in 1864 and which, somehow, escaped the attention of entomologists until Craighead (1923) referred to it. Walsh (1864-1865) was probably the first entomologist to express the idea of the principle. He concluded, from numerous observations in nature as well as by experiments on plant-feeding and wood-boring beetles, that host-preferences existed. Such preferences, he suggested, become habituated and would finally lead to the formation of separate species.

Reviewing the available literature dealing with the host-selection principle, it became obvious that some evidence lend strong support to the principle while with other insects there was no indication that the principle will hold. A few instances might be mentioned below.

Craighead (1922) (cited by Larson, 1927), after years of careful experimentation with certain cerambycid wood-boring beetles (including *Cyllene pictus, Neoclytus caprea, Callidium antennatum* and *Molorchus bimaculatus*), concluded that in practically all the species experimented with the adults showed a marked predilection for the host in which they have fed as larvae, provided they were not deterred by other factors, such as the unfavourable condition or the small quantity of the host. He also came to the conclusion that continued breeding in a given host-wood intensified the without of Walsh's work published in 1864 ans which, somehow, escaped the preference for that host.

Also, Thorpe's experiments (1929-1930) with the Ermine moth, *Hyponomeuta padella* L., lend strong support to the host-selection principle. He found that the moths reared from hawthorn and blackthorn when given the choice of plants for egg-laying, laid 79.3% of their eggs on hawthorn and blackthorn, and only 20.7% of the eggs were deposited on apple. Similarly, moths of the apple race laid 90.25% of their eggs on apple, whereas only 9.75% of the eggs were deposited on hawthorn and blackthorn. Again, the hawthorn and blackthorn reared moths, each in turn showed a marked predilection for oviposition on the original host in which they had been bred.

On the other hand, Quayle (1926) (cited by Larson, 1927) found that the principle did not apply to the codling moth, *Carpocapsa pomonella*. He found that the moths that were reared from apple oviposited equally freely on walnut and apple, as well as on pear and some other fruits that were in the same cage. Likewise, moths reared from walnut also oviposited equally freely on the same fruits, apparently showing no discrimination. Moreover, copulation appeared to occur as freely between insects having bred in different hosts as with insects having bred in the same hosts. In other words, the breeding of the moths either from the apple or from the walnut did not cause the choice of that particular host for oviposition, that is, there was no indication towards the formation of differend species or varieties.

Another instance of the principle not applying is that given by Larson (1927) concerning *Bruchus quadrimaculatus* Fab. (= *Callosobruchus maculatus* F.). This author described many experiments and observations after which he quoted: «This indicates that there are certain seeds which are favored for oviposition and certain ones which are avoided. The fact that the weevils consistently avoid oviposition on certain varieties of seeds even after having bred therein for several generations indicated that there is no inherited predilection for that host. Continued breeding a in a host does not appear to intensify the preference for that host».

Zaazou (1951) also came to the conclusion that the principle did not hold for the three Bruchids experimented with, namely, *Bruchus*

(*Acanthoscelides*) *obtectus* Say, *Bruchus* (*Callosobruchus*) *maculatus* F., and *Bruchus* (*Callosobruchus*) *chinensis* L. As regards *B. maculatus,* the results of his experiments showed that although the insects were bred from broad beans there was a marked preference for cowpeas (the favourite host) which received the highest number of eggs. He also added that the preference for cowpeas for oviposition was correlated with the age of the adult weevils, it being especially marked during the first half of the adult's life, whereas during the second half of the life of the adults the attraction for the favourite host got weaker, and the insects oviposited indiscriminately on all the different hosts.

It is, therefore, evident from the works of Larson (1927) and Zaazou (1951) that the host-selection principle did not apply to the four-spotted cowpea weevil, *Bruchus* (*Callosobruchus*) *maculatus* F. The former author used in his experiments insects that were bred for two to eight generations in broad windsor beans, dwarf sugar peas, blackeyed cowpeas, or red ripper cowpeas; whereas the second author used Bruchids that were bred on broad beans for nearly six months.

The present writer, during his work on the bilogy of *Bruchus* (*Callosobruchus*) *maculatus,* thought it appreciable to obtain additional evidence related to the host-selection principle as applied to the mentioned Bruchid using chickpeas (*Cicer arietinum*) to breed the experimental insects. In other words, the writer wanted to investigate that the progeny of a four-spotted cowpea weevil, if they were to be forced to breed in the chick-pea for so many generations, would they acquire preference for that new host for oviposition and, consequently, would a monophagous variety that breeds only in chick-peas be adopted ?

TECHNIQUE

The different hosts to be used either for breeding the experimental insects or for ovipositing on, were first cleaned and sterilized by heating in an oven at 80-90° F. for six hours. They were then kept before use at 75 % relative humidity for at least six weeks which was the time required for conditioning the seeds to that humidity.

The insects used in the experiments were all newly-emerged, that is, they were less than half an hour old, since the writer found that the first egg might be oviposited within half an hour from copulation which occurred any time after emergency. All the insects were obtained from cultures kept at a constant temperature of 25° C. and a constant relative humidity of 75 %.

Petri-dishes were divided by cardboard stripes into eight compartments. Four of these compartments were large and intended to receive the different hosts. The other 4 compartments, which were smaller and alternated with

the larger ones, were left vacant for the introduction of the experimental weevils. Separating the hosts from each other by empty compartments eliminated the probability that the females might be stimulated by an attractive host to oviposit on an adjoining less attractive one. The cardboard stripes were all constructed so as to leave a clearance of one centimeter distance from the top of the Petri-dish to allow of free movements of the contained insects.

The hosts were always arranged in the compartments in the same sequence throughout all the dishes. Each compartment of every dish received a number of host-seeds just enough to fill it. In this manner every dish required 25 seeds of cowpeas (*Vigna sencnsis*), 25 of chick-peas (*Cicer arietinum*), 20 of *Phascolus vulgaris* (Suisse blanc), and 40 seeds of sweet peas (*Pisum sativum*). This procedure permitted of equal surface areas of hosts exposed to the experimental insects.

In each Petri-dish were introduced 8 newly-emerged Bruchids (4 males and 4 females). To ensure a fair and unbiased distribution of the weevils among the hosts, one couple (♂ + ♀) was introduced in each of the smaller compartments. The weevils being introduced, the dishes were then covered with muslin held in place by rubber bands.

The dishes were then put in desiccators containing KOH solution which maintained the internal humidity at 75% R.H. The desiccators were then placed in an incubator kept constantly at 25° C. To eliminate the effect of light, the incubator was kept in a dark room throughout the experiments.

The insects in each dish were left to oviposit on the different hosts for a period of days after which the hosts were removed and the eggs on each counted. The same insects were then distributed on the compartments of a clean Petri-dish containing the same number of fresh host-seeds which were arranged in the same order as before. Then the Bruchids were left undisturbed until they all died when the eggs on each host were counted.

Experiment I

In this experiment, the Bruchids used were reared on blackeyed cowpeas for 10 generations at 25° C. and 75% R.H. The different hosts used as oviposition site were blackeyed cowpeas, chick peas, common beans (*Phascolus vulgaris*) and sweet peas. Ten trials were made. The results are presented in Table I.

It is evident from the above Table that, during both periods of the adults' life, the blackeyed cowpeas received the highest percentage of eggs. It was followed (in order of the number of eggs received) by the common beans (*Phascolus*), then the sweet peas, and lastly came the chick-peas which were practically avoided by the ovipositing females.

TABLE I

Oviposition records on the different hosts of four mated females of Bruchus (Callosobruchus) maculatus *reared in blackeyed cowpeas.*

NUMBER OF TRIAL	NUMBER OF EGGS DEPOSITED ON EACH HOST DURING : FIRST PERIOD OF ADULTS' LIFE				SECOND PERIOD OF ADULTS' LIFE			
	BLACKEYED COWPEAS	PHASEOLUS VULGARIS	SWEET-PEAS	CHICK-PEAS	BLACKEYED COWPEAS	PHASEOLUS VULGARIS	SWEET-PEAS	CHICK-PEAS
1	127	61	29	—	16	6	1	—
2	161	32	13	—	14	12	12	—
3	61	126	2	1	11	16	12	—
4	128	49	25	—	12	3	11	—
5	171	25	—	—	11	10	—	—
6	168	28	—	1	10	6	9	—
7	137	65	22	—	6	11	8	—
8	78	113	23	—	11	13	12	—
9	67	115	51	—	10	11	5	—
10	77	99	44	—	10	2	9	—
TOTAL EGGS	1175	713	239	2	111	90	79	—
AVERAGE	117.5	71.3	23.9	0.2	11.1	9	7.9	—
PERCENTAGE	55.19	33.49	11.23	0.09	39.64	32.14	28.22	—

However, the preference for blackeyed cowpeas was much more marked during the first four days of the adults' life than at the second period, the percentage of eggs laid on them being 55.19 and 39.64 %, respectively. This indicated that the attraction of blackeyed cowpeas got weaker as the Bruchids grew older.

Table I also showed that during the first period of adults' life, the order of preference for the hosts was very much pronounced. But, in the second period of oviposition, apart from the chick-peas, there, was not much discrimination between the different hosts, the figures for the percentage eggs being much closer to each other than they were at the first period of the adults' life.

Experiment II

The Bruchids used in this experiment were reared from chick-peas for six successive generations at 25° C and 75% R.H. The different hosts used were the same as in Experiment I. Ten trials were made. The results are shown in Table II.

The results of Experiment II also showed that during both periods of the adults' life, blackeyed cowpeas were the favourite host. Chick-peas, on which the Bruchids were successfully reared for six generations, proved not

TABLE II

Oviposition records on the different hosts of four mated females of Bruchus (Callosobruchus) maculatus *reared in chickpeas*

NUMBER OF TRIAL	NUMBER OF EGGS DEPOSITED ON EACH HOST DURING :							
	FIRST PERIOD OF ADULTS' LIFE				SECOND PERIOD OF ADULTS' LIFE			
	BLACKEYED COWPEAS	PHASEOLUS VULGARIS	SWEET-PEAS	CHICK-PEAS	BLACKEYED COWPEAS	PHASEOLUS VULGARIS	SWEET-PEAS	CHICK-PEAS
1	85	89	40	—	19	10	7	—
2	109	87	33	—	20	13	11	—
3	98	93	56	—	3	18	2	1
4	140	73	—	—	11	3	—	—
5	158	55	—	—	12	10	9	—
6	155	59	—	—	21	12	40	—
7	91	76	71	2	22	5	7	—
8	113	103	13	5	13	6	8	—
9	160	68	—	—	16	29	10	—
10	191	69	—	—	18	7	18	—
TOTAL EGGS	1300	772	213	7	155	113	82	1
AVERAGE	130	77.2	21 3	0.7	15 3	11.3	8.2	0.1
PERCENTAGE	56.72	33.88	9.29	0.31	44.16	32.19	23.36	0.29

only that it was not the preferred host, but also that it was practically avoided by the female weevils. This indicated that the continued breeding of *Callosobruchus maculatus* in chick-peas for six generations did not result in a preference for that host for oviposition; that is to say, the host-selection principle did not apply once more to this Bruchid.

In this experiment too, the attraction for blackeyed cowpeas was weakened during the second period of the adults' life. Here also, excluding chick-peas, the discrimination between the different hosts was much less pronounced as the Bruchids got older.

Thus, it became apparent from both experiments that the age of insects affected their selection of their favourable hosts. The attraction for the favourite host (cowpeas) was very strong during the first half of the adults' life, but it got weaker during the second half of the adults' life and the weevils oviposited indiscriminately on all the different hosts except chick-peas. The interpretation given by Zaazou (1951) for this phenomenon is very reasonable. He proposed that the chemical sense by which insects choose their hosts did not remain constant throughout the life of the Bruchids, but that it was stronger when the insects were young and grew weaker as they got older.

SUMMARY

(1) Two experiments were carried out at 25° C. and 75 % R. H. using blackeyed cowpeas and chick-peas, respectively, as rearing hosts for *Bruchus* (*Callosobruchus*) *maculatus* F.

(2) The host-selection principle did not apply for this insect when it was bred in chick-peas for six generations. In fact, chick-peas were practically avoided by the experimental insects.

(3) In both experiments, the blackeyed cowpeas were the favourite host.

(4) During the first 4 days of the Bruchids' life, the attraction for blackeyed cowpeas was stronger than during the rest of the insects' life.

(5) During the second period of the adults' life, the insects oviposited indiscriminately on all the hosts except chick peas.

(6) The sense of smell, which is responsible for the choice of hosts, varies with the age of the Bruchids, it being very strong when the insects were young but got weaker as they grew older.

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A list of insects found on plants of economic importance in Syria

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This list has been compiled after four years of collecting in the different parts of Syria. Syrian agriculture suffers from many serious pests most of which occur in Lebanon. However the degree of seriousness of a pest found in both countries might differ very much, due to the differences in the climatic conditions of both countries, the area under cultivation of a particular crop, and the possibility of control application.

Lebanon lies mostly on the Mediterranean shore except for a narrow valley called the Bekaa, which is separated from the sea by the eastern slope of Mt. Lebanon. The total rainfall in most of Lebanon is around one meter per year, except for the Bekaa where it goes down to around 500 mm. Syria on the other hand, had a small fraction of its area on the Mediterranean shore with a rainfall ranging from 650-1.200 mm. per year, while about 90% of its area lies in a region having a typical dry continental climate of a total rainfall of 200 mm. or less, except for a narrow strip all along the Turkish border where the rainfall goes to a total of 350-550 mm. per year.

Lebanon with an area of 4.000 square miles, and a population of one million is almost all for intensive agriculture. Syria has an area of 66.000 square miles and a population of 3.177.751, goes mostly for extensive agriculture. The Table below compares the areas allocated to the more important crops in both countries.

CROP	AREA IN LEBANON IN HECTARES	AREA IN SYRIA IN HECTARES
Wheat, barley, corn, rice, sorghum	105.000	1.468.200
Vegetables	16.040	26.790
Olive trees	16.000	79.911
Vine-yards	20.000	67.468
Citrus trees	12 000	750
Stone fruit trees	4.650	12 900
Pome fruit trees	4.350	4.863
Cotton	less than 1.000	217.352

Land ownership differs much in both countries. In Lebanon very few people own any tracts of land that exceed an area of 15 hectares though

some of these few might own very much larger areas. In Syria the situation is different: very few people (if they own anything at all) own as little as 10-15 hectares, and the majority of land owners own areas in the magnitude or more hectares. The smaller areas in Lebanon facilitate easy control while of few hundred hectares, while some own several thousand or tens of thousands the larger areas in Syria cause a real difficulty in control applications and lots of expense.

LIST OF INSECTS

Nota bene: When the name of the insect is followed by three asterisks it means that the insect is of very great importance; when followed by two asterisks it means that it is serious; when followed by one, it means that it occasionally needs control. When the name is not followed by an asterisk the insect is of no economic importance as yet.

A. Pome fruit insects

Lepidoptera : 1. *Saturnia pyri* L. (Saturnidae)! 2. *Zeuzera pyrina* L. *** (Cossidae); 3. *Chloridae nubigera* H.-S. (Agrotidae); 4. *Carpocapsa pomonella* L. *** (Tortricidae); 5. *Hyponomeuta malinellus* F. (Hyponomeutidae); 6. *Lyonetia clerckella* L. * (Lyonetidae). — Coleoptera : 7. *Polyphylla fullo* L. * (Scarabaeidae); 8. *Scolytus rugulosus* Ratz. * (Scolytidae). — Diptera : 9. *Ceratitis capitata* Wied. ** (Trypaneidae); 10. *Apiomyia bergenstammi* Wacht. * (Cecidomyidae). — Hemiptera : 11. *Stephanitis pyri* F. * (Tingidae); 12. *Eriosoma lanigera* Hausm. *** (Aphididae); 13. *Aphis pomi* de Geer ** (Aphididae); 14. *Parlatoria olea* (Colv.) ** (Coccidae); 15. *Aspidiotus hederae* Vallot *** (Coccidae); 16. *Psylla pyricola* Forst. *** (Psyllidae). — Acarina : 17. *Eriophyes pyri* Pagenstecher * (Eriophyidae); 18. *Brevipalpus pyri* Sayed (Tetranychidae).

B. Stone fruit insects

Lepidoptera : 1. *Diloba caeruleocephala* L. ** (Agrotidae); 2. *Saturnia pyri* L. (Saturnidae); 3. *Anarsia lineatella* Z. ** (Gelechidae). — Coleoptera : 4. *Cerambyx dux* Fald. * (Cerambycidae); 5. *Capnodis tenebrionis* L. *** (Buprestidae); 6. *Perotis chlorana* Fuessl. * (Buprestidae); 7. *Rhynchites trojanus* Gyll. *** (Curculionidae); 8. *Scolytus rugulosus* Ratz. ** (Scolytiidae). — Diptera : 9. *Ceratitis capitata* Wied. *** (Trypaneidae); 10. *Drosophila melanogaster* Meig. (Drosophilidae). — Hemiptera : 11. *Monosteira lobulifera* Reut. (Tingidae); 12. *Pterochlorus persicae* (Chol.) ** (Aphididae); 13. *Brachycaudus helichrysi* (Kalt.) ** (Aphididae); 14. *Aphis* sp. ** (Aphididae). — Hymenoptera : 15. *Cymbex quadrimaculatus humeralis* * (Tenthredinidae); 16. *Eurytoma amygdali* End. ** (Chalcididae). — Acarina : 17. *Eriophyes* sp. ** (Eriophyidae).

C. Miscellaneous fruits

Lepidoptera : 1. *Deudorix livia* Klug **, on pomegranate (Lycaenidae); 2. *Zeuzera pyrina* L. **, on pomegranate (Cossidae). — Diptera : 3. *Lonchea aristella* Becker *, on fig (Sapromizidae). — Hemiptera : 4. *Aphis gossypii* Glov. *, on pomegranate (Aphididae); 5. *Ceroplastes rusci* L. **, on fig (Coccidae); 6. *Homotoma ficus* Guer., on fig (Psyllidae); 7. *Trioza buxtoni* Laing, on fig (Psyllidae).

D. Olive Trees

Lepidoptera : 1. *Zeuzera pyrina* L. ** (Cossidae); 2. *Prays oleellus* F. * (Tineidae). — Coleoptera : 3. *Phloeotribus scarabaeoides* Bern. ** (Scolytidae); 4. *Hylesinus oleiperda* F. * (Scolytidae). — Diptera : 5. *Dacus olea* Rossi *** (Trypaneidae); 6. *Perrisea olea* Loew (Cecidomyidae). — Hemiptera : 7. *Aspidiotus hederae* Vallot ** (Coccidae); 8. *Saisseta olea* Loew (Coccidae); 9. *Euphyllura olivina* Costa ** (Psyllidae); 10. ? *Aleurodes olivinus* Silv. (Aleurodidae). — Thysanoptera : 11. ? *Phleothrips oleae* Costa.

E. Citrus

Diptera : 1. *Ceratitis capitata* Wied. *** (Trypaneidae); 2. *Drosophila melanogaster* Meig. (Drosophilidae). — Hemiptera : 3. *Toxoptera aurantii* Koch * (Aphididae); 4. *Chrysomphalus aonidium* L. (= *ficus* Ashm.) ** (Coccidae); 5. *Aonidiella aurantii* Mask. ** (Coccidae); 6. *Ceroplastes floridensis* Comst. ** (Coccidae); 7. *Pseudococcus citri* Risso ** (Coccidae); 8. *Icerya purchasi* Mask. * (Coccidae).

F. Grape-vine

Lepidoptera : 1. *Saturnia pyri* L. (Saturnidae); 2. *Celerio lineata livornica* Esp. (Sphingidae); 3. *Theresa* (*Ino*) *ampelophaga* Bayle ** (Zygaenidae); 4. *Polychrosis botrana* Schiff. ** (Tortricidae). — Hemiptera : 5. *Chloropsalta viridissima* Walk. *** (Cicadidae); 6. *Phylloxera vastatrix* Planch. ** (Aphididae); 7. *Pseudococcus vitis* Niet. ** (Coccidae). — Thysanoptera : 8. *Retithrips syriacus* Mayet. — Acarina : 9. *Eryophyes vitis* Pang. (Eriophyidae).

G. Cotton

Lepidoptera : 1. *Vanessa cardui* L. (Nymphalidae); 2. *Earias insulana* Boisd. *** (Noctuidae); 3. *Chloridea* (*Heliothis*) *obsoleta* F. ** (Noctuidae); 4. *Agrotis ypsilon* Rott. ** (Noctuidae); 5. *Prodenia litura* F. *

(Noctuidae); 6. *Laphygma exigua* Hb. (Noctuidae); 7. *Sphynx convolvuli* L. (Sphyngidae); 8. *Platyedra gossypiella* Saunders ** (Gelechidae). — Hemiptera: 9. *Nezara viridula* L. (Pentatomidae); 10. *Creontiades pallidus* Rb. ** (Miridae: Capsidae); 11. A. Jassid gen. sp. (Jassidae); 12. *Aphis gossypii* Glov. * (Aphididae). — Thysanoptera: 13. *Thrips tabaci* Lind. ** — Acarina: 14. *Eotetranychus telarius* L. ** (Tetranychidae).

H. Vegetable insects

a. Cruciferae

Lepidoptera: 1. *Pieris brassicae* L. * (Pieridae); 2. *Pieris rapae* L. (Pieridae); 3. *Mamestra brassicae* L. (Noctuidae); 4. *Agrotis ypsilon* Rott. (Noctuidae); 5. *Plutella maculipennis* Curt. (Plutellidae). — Coleoptera: 6. *Phyllotreta atra crucifera* Goeze (Chrysomelidae). — Hemiptera: 7. *Eurydema festivum* L. (*pictum* H.S.) ** (Pentatomidae); 8. *Eurydema festivum decoratum* (H.S.) ** (Pentatomidae); 9. *Eurydema rugulosum* Dhrm. * (Pentatomidae); 10. *Brevicoryne brassicae* L. ** (Aphididae).

b. Solanaceae

Lepidoptera: 1. *Agrotis ypsilon* Rott. * (Agrotidae); 2. *Prodenia litura* F., on pepper (Agrotidae); 3. *Phthorimea* (*Gnorimoschema*) *operculella* (Zell.) ** (Gelechidae) (1). — Coleoptera: 4. *Polyphylla fullo* L. ** (Scarabaeidae). — Orthoptera: 5. *Gryllotalpa vulgaris* L. ** (Gryllidae). — Acarina: 6. *Eotetranychus telarius* L. ** (Tetranychidae); 7. *Phyllocoptes destructor* Kiefer ** (Eriophyidae).

I. Graminae

a. Wheat and barley

Lepidoptera: 1. *Agrotis segetum* Schiff. (Agrodidae); 2. *Agrotis ypsilon* Rott. (Agrotidae); 3. *Syringopais temperatella* Ld. ** (Elachistidae); 4. *Sitotroga cerealella* Oliv. * (Gelechidae). — Coleoptera: 5. *Marseulia dilativentris* Reiche * (Chrysomelidae). — Hemiptera: 6. *Eurygaster integriceps* Put. *** (Pentatomidae) (2); 7. *Macrosiphum* sp. (Aphididae).

b. Maize and sorghum

Lepidoptera: 1. *Agrotis ypsilon* Rott. (Agrotidae); 2. *Chloridae obsoleta* F. ** (Agrotidae); 3. *Pyrausta nubilalis* Hb. ** (Pyralidae). —

(1) Omitted by mistake from «A list of insects observed on economically important plants and plant products in Lebanon», in *Bull. Soc. Fouad Ier Entom.*, XXXIV, pp. 133-141, Cairo.

(2) *Eurygaster integriceps* Put. is not serious at all in Lebanon, and the three asterisks in my paper « A list of insects observed on economically important plants and plant products in Lebanon » should be deletted.

Coleoptera : 4. *Chaetocnema chlorophana* Duft. (Chrysomelidae). — Hemiptera : 5. *Aphis maidis* Fitch. ** (Aphididae).

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The effect of weevily-seeds on the oviposition of *Bruchus (Callosobruchus) maculatus* F.

[Coleoptera : Bruchidae]

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INTRODUCTION

The oviposition of various Bruchids has been studied extensively. One of the factors that affect oviposition in such insects is the previous infestation of hosts. The few workers who dealt with the latter subject have tackled it from the stand-point of host-selection, i.e., the discrimination of female Bruchids, for their oviposition, between sound hosts and infested ones when they were given the choice of both, or from the point of view of the factors that govern the females in such a selection of hosts for oviposition. To give an example, Zaazou (1953) conducted several experiments with *Bruchus* (*Acanthoscelides*) *obtectus* Say, *Bruchus* (*Callosobruchus*) *maculatus* F., and *Bruchus* (*Callosobruchus*) *chinensis* F., after which he concluded that sound beans are preferred for oviposition to infested seeds, the latter receiving not more than 15% of the total eggs laid by the females. He also came to the conclusion that, as artificial holes or cracks made in the sound beans did not increase the number of eggs laid on them, the preference of sound beans to infested ones would be due mainly, if not solely, to the peculiar smell of infested beans which repelled the female Bruchids.

As far as the writer is aware, apparently nothing has been done on the effect on oviposition of infested seeds when sound ones are not available to the ovipositing females. In other words, if the female Bruchids were to be forced to lay their eggs on previously-infested seeds, would that stimulate oviposition, or would it reduce the number of eggs laid ?

To investigate this effect, the following experiment was carried out with the 4-spotted cowpea weevil, *Bruchus* (*Callosobruchus*) *maculatus* F.

TECHNIQUE

Previously infested blackeyed cowpeas, each having at least one emergence hole, were freed from any contained eggs. They were, as well as sound cowpeas and sound cowpeas with artificial holes made on them, sterilized

by heating to 80-90°F. for 6 hours, and then conditioned at 75% R.H. for at least 6 weeks before being used.

30 glass vials, 2x1 inches, were used. Each of the first 10 vials received 20 seeds of infested cowpeas. Into each of the second group of 10 vials was placed 20 seeds of sound, uninfested cowpeas. The remaining 10 vials, each received 20 seeds of sound cowpeas with artificial holes made on them.

In each vial were introduced 4 adults of the cowpea weevil, 2 males and 2 females. The adult weevils used were obtained from the same culture of weevils which was kept always at 25°C. and 75% R.H. All the adults used in the experiment were newly-emerged, i.e., less than half an hour old (the writer, previous paper in this Bulletin).

The weevils being introduced, the vials were covered with muslin secured by rubber bands and then placed in a desiccator maintained at a R.H. of 75%. The desiccator was put in an incubator at a temperature of 25°C. Under such conditions, the adult Bruchids were left undisturbed until their death occurred when the eggs on the seeds of each vial were counted.

RESULTS

The results of this experiment are shown in the following Table.

Number of eggs laid by two mated females of Bruchus (Callosobruchus) maculatus *on sound cowpeas, infested cowpeas, and cowpeas with artificial holes respectively.*

NUNBER OF TRIAL	NUMBER OF EGGS LAID ON:		
	SOUND COWPEAS	INFESTED COWPEAS	COWPEAS WITH ARTIFICIAL HOLES
1	102	189	98
2	101	137	105
3	107	171	115
4	112	170	116
5	105	101	100
6	109	148	102
7	104	167	106
8	114	172	97
9	106	125	113
10	100	146	103
TOTAL EGG.	1060	1526	1055
AVERAGE	106	152.6	105.5

It is clear from the above Table that the previous infestation of seeds increased the number of eggs laid by the female Bruchids from 106 to 152.6, an increase of 42% which was highly significant.

There are only two differences between sound cowpeas and infested ones : (1) the peculiar smell of infested seeds ; and (2) the emergence holes found on weevily-cowpeas. So, the increase in the number of eggs laid on infested cowpeas might be due to one, or either, of these factors.

Comparing the second and last columns of the Table, it became evident that artificial holes made in sound cowpeas did not result in a significant change in the number of eggs laid on them. It is also well-known (Larson and Fischer, 1938) that the cowpea weevil avoids ovipositing on seeds having broken or loose seed coats.

It follows then, that the peculiar smell of infested cowpeas was probably the only cause of the increase in the number of eggs laid on them. This smell might have acted as a stimulant to oviposition.

SUMMARY

(1) Forcing the females of the 4-spotted cowpea weevil to oviposit only on previously-infested cowpeas caused a significant increase of approximately 42 % in the number of eggs laid.

(2) There was no difference between the number of eggs laid on sound cowpeas and those with artificial holes made on them.

(3) The peculiar smell given off from infested cowpeas probably acted as a stimulant to oviposition.

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Damage caused to Cotton leaves by *Tanymecus musculus* Fahrs.

[Coleoptera : Curculionidae]
(with 2 Text-Figures)

by Ibrahim Bichara,
Senior Entomologist, Ministry of Agriculture, Cairo.

Tanymecus musculus Fahrs. (Fig. 1) is not new to Egypt, but incidence of damage to cotton was not previously reported. Although it is not considered as a pest, not even a minor pest, but it was thought interesting to put on records the few cases of attack noticed so far.

Late in May 1937, the attention of the Entomological Section was drawn to a new type of damage to cotton plantations in some villages of Girga Province, about 300 miles south of Cairo. On visiting the place, noticeable injury to cotton leaves was seen in some fields which were previously grown with clover. Beneath the plants in the affected areas, numerous dark brown weevils, about one centimetre long, were hiding a few inches under the soil. In heavily infested sections, about 10 to 15 weevils could be found per hole. This is equivalent to some 300.000 weevils per acre. At sunset (7 p.m.) or a short time after sunset, they start to crawl out and climb up the plants. They feed on the leaves all night, and return back to the soil at sunrise (about 5 a.m.). Damage starts with the lower leaves and when these are nearly consumed, the higher leaves are later attacked. By the end of June or the first week of July the weevils almost disappear and no further injury is noticed. The attacked plants are not killed by the injury; they soon recover and produce fresh leaves, although they do not produce their full crop. The weevils are more noticeable on fairly dry fields and in places with abundance of weed growth. On watered fields, the weevils are found in the top two inches of soil; on dry fields they may hide 8 or 10 inches below, mostly in the cracks. When the flood water comes in August or early September, many weevils are seen crawling on the banks of the basins, seeking shelter under the bark of *Acacia* or other trees, or in weeds.

There are no exact figures on the areas that showed weevil damage, but they are certainly very small. In 1937 about 120 acres of cotton were reported, in 1938 no reports, in 1939 about 150 acres, and in 1940 almost none. Very little was reported thereafter.

Besides cotton, the weevils were found on millet, okra (*Hibiscus esculentus*), Jew's Mallow (*Corchorus olitorius*) and on some weeds. The areas affected were small.

Fig. 1 : *Tanymecus musculus* Fahrs., × 10 (B. Assaad del.).

The weevil was kindly identified by Dr. H. Priesner. In the collection of the Entomological Section, Ministry of Agriculture, records go as back as 1911. Samples were received from almost all Provinces of Upper Egypt from June to December.

In 1937 and again in 1939, several insecticides were tried under laboratory conditions. The weevils usually refrained from feeding on the dusted leaves, and when forced by hunger, very little feeding was attempted. When undusted and dusted leaves were put together, they fed exclusivly on the undusted leaves. Under such conditions mortality was very low. The materials tested comprised calcium arsenate, lead arsenate, Paris green, Paris green and lime 1:5, sodium fluosilicate, barium fluosilicate, potassium fluosilicate, cryolite, barium chloride, etc. None of the dusted materials was cherished. As no attack had been reported to us during the last seven or eight years, there was no chance to test new organic insecticides, such as DDT, benzene hexachloride, toxophene or phosphorous compounds.

When a few boys were given pails with some water and a little kerosene

Fig. 2: Cotton leaves damaged by *Tanymecus musculus* Fahrs.

on the top, mere shaking of the plants brought a hundreds of weevils in the pails where they quickly died. But this means night work, may be several consecutive nights. No detailed life-history was attempted, as the insects had been of very *little importance* up to the present time.

A casual stem-borer of Cotton Plant

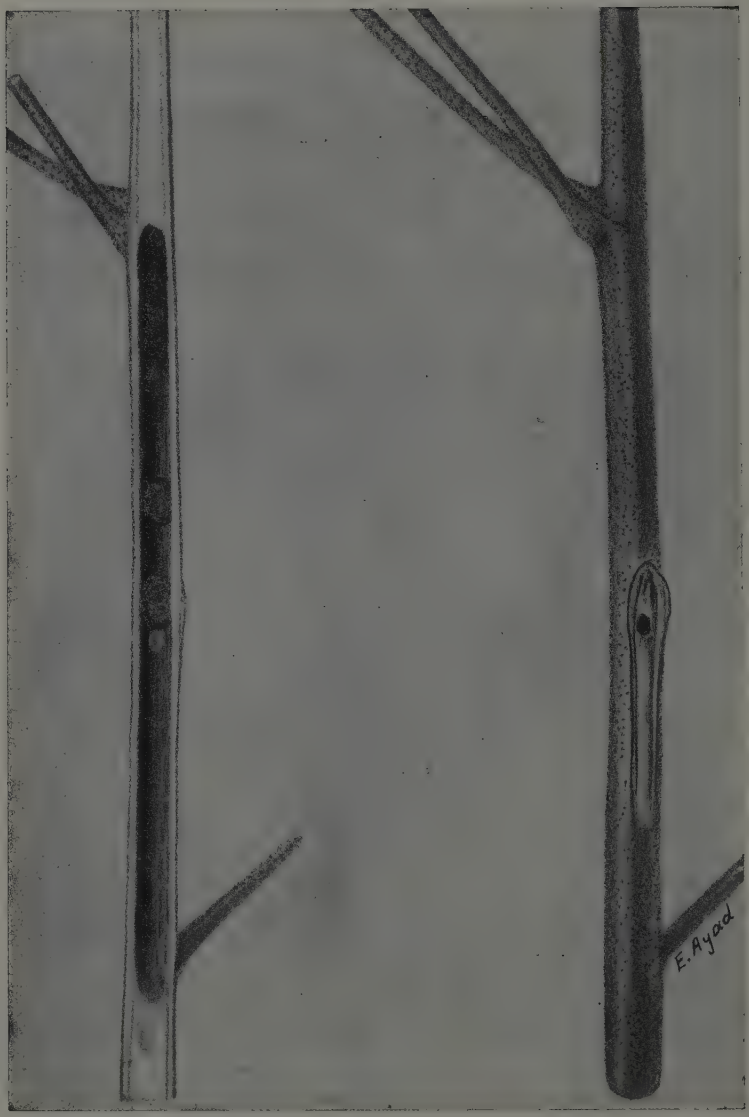
[Hymenoptera : Sphecoidea-Crabronidae]
(with 5 Text-Figures)

by Ibrahim Bichara,
Senior Entomologist, Ministry of Agriculture, Cairo.

During the last week of June 1948, two cotton plants were found in one of the plots of the Plant Breeding Section, Giza, showing symptoms of

Fig. 1: *Crabro* (*Solenius*) *laevigatus* Dest., × 7.5 (B. Assaad del.). — Fig. 2: Larva of same, × 15 (E. Ayad del.). — Fig. 3: Cocoons of same inside cotton stem, × 3 (E. Ayad del.).

damage not previously recorded. A conspicuous hole (Fig A.) was seen in the middle of the main stem leading to an internal tunnel (Fig. B) about 13 cms. long, filled with insect frass as well as the remains of several adult flies



A B

Conspicuous hole (Fig. A) leading to internal tunnel (Fig. B).

belonging to different families (Muscidae, Tachinidae, etc.). Two ochreous oblong cocoons (Fig. 3) found in one of the stems were bred to the adult stage, and on July 10th the emerging insects were kindly indentified by Prof. Dr. H. P r i e s n e r as *Crabro* (*Solenius*) *laevigatus* Dest. (Fig. 1). One of the plants showed wilting above the damaged area.

On July 18th another damaged plant was found, and two more on July 25th. On this latter date, the plant of the previous week was found completely broken in the middle by wind action. Dissection of the stems showed the usual tunnels excavated by the adult female, with two larvae in one of them, several small flies, frass, etc. Little chips of wood from the burrowed stem were clearly noticeable on the upper surfaces of the lower leaves of the affected plants.

On June 7th 1949, a cotton plant showing the same type of damage was noticed on Gemmaiza Experimental Farm, in the middle of the Delta (about sixty miles north of Cairo). The usual tunnel, seven centimeters long, contained the larva of *Crabro* (Fig. 2) with numerous small flies. Small bits of excavated wood were also noticed on the leaves of the affected plant.

Dr. P r i e s n e r states that this group of insects usually chooses plants with hollow stems, such as grasses, for stuffing with the insects that are captured, stung, and carried to serve as food for its young. This habit of excavating and burrowing inside the cotton stem must be very rare, else it would have been a bad pest. The insect is not new to the country, and the first anxiety of a new cotton pest was fortunately removed.

Analysis of the influence of single weather factors on flighting and on changes in weight of scale-hives of honeybees at Rothamsted

(with 7 Text-Figures and 17 Tables)

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Introduction. — Method. — Nectar and pollen sources at Rothamsted. — Daily fluctuation in changes in colony weight and period of flighting. — Interrelation of weather factors. — Correlation. — Data examined. — What is the gain in colony weight? — Night loss in colony weight. — The relationship between hours of flying activity and changes in colony weight. — Temperature. — Daily range of temperature. — Ground temperature. — Solar radiation and sunshine. — Air moisture. — Rain. — Barometric pressure. — Wind. — Conclusion and Summary. — Acknowledgments. — References.

INTRODUCTION

In order to obtain information on the effects of weather factors on the honeybee (*Apis mellifera* L.), experiments and field observations were commenced at Rothamsted Experimental Station, Harpenden, Herts, England, about twenty years ago. A number of hives containing healthy colonies of honeybees in the « Home Apiary » at Rothamsted were placed on balances and have had their weights continuously recorded automatically since July 1927.

Many interesting results have been obtained in these studies of flying activity. It has been shown conclusively that weather factors greatly influence flying activity and the amount of honey produced.

In the first place weather factors act directly on the activities of the members of the colony both inside and outside the hive; they also exert an indirect effect on the bees by influencing the provision of nectar and pollen by bee-plants. These two effects of weather, directly upon the bee herslef and indirectly upon the bee through the flowers, occur simultaneously, the flowers not being attractive to bees when weather conditions prohibit flying.

From these studies which have been mainly directed towards economic ends, several lines of work of more fundamental interest have gradually developed.

METHOD

This work is based upon a study of the relationship between the daily fluctuations in the total weights of a number of colonies of honeybees and the number of hours of flying activity, which, of course, give a measure of the activity of the bees in these colonies, and the changes in colony weights and meteorological data collected in the vicinity of the apiary where these colonies were maintained.

NECTAR AND POLLEN SOURCES AT ROTHAMSTED

The principal sources of nectar and pollen at Rothamsted are probably white clover and lime (*Tilia vulgaris*), but in most years some crops such as red clover, sanfoin and field beans were also available. S y n g e (1946) made an analysis of pollen trap catches at Rothamsted, and from this compiled a list of the main sources of pollen in the district. This list is given in Table I which will throw a light on Rothamtsed flora.

DAILY FLUCTUATION IN CHANGES IN COLONY WEIGHT AND PERIOD OF FLIGHTING

A comparison of the curves of changes in colony weight and number of hours of flighting (Figs. 1 and 2) with the main weather factors curves in the same periods shows that these factors have a considerable influence on the size of the changes in colony weight and the length of flighting period; and that the fluctuations in colony weight and period of flighting can be correlated with single weather factors, e.g., changes in weight apparently increase with a rise in temperature, and decreases with a fall. The relative effects of the various factors are greater the farther the condition departs from the normal. The largest increase in colony weight and the longest period of flighting were made when all the factors were at or near their optima.

In order to show these effect more clearly, charts were made (Figs. 3 and 4) by plotting the changes in colony weight and hours of flighting against some of the most important weather factors.

INTERRELATION OF WEATHER FACTORS

Weather factors are, however, interrelated in a complex manner, and an example of this complexity is provided in Table II which is copied with slight modification from the data of W i l l i a m s (1940).

TABLE I

Main pollen sources at Rothamsted (after Synge, 1946)

POLLEN SOURCES	EARLY SPRING	SPRING	MID-SUMMER	AUTUMN
MAIN. . . .	Fraxinus excelsior, Populus, Ulmus glabra.	Crataegus, Prunus, Pyrus.	Onobrychis sativa, Red clover, Sinapis sinapistrum, White clover.	Brassica alba, Hedera helix.
IMPORTANT .	Buxsus sempervirens, Cupressus or Taxus, Salix.	Acer, Aesculus, Aubretia, Berberis, Brassica oleracea, Betula, Quercus, Salix, Taraxacum, Ulex.	Bryonia dioca, Castanea sativa, Cynarcea (Thistles), Epilobium angustifolium, Filipendula ulmaria, Papaver rhoeas, Ranunculus, Rosa, Rubus (blackberry, Vicia faba.	Aster type, Dahlia, Rosa, Taraxacum type, Veronica.
UNIMPORTANT	Anemone, Aster type, Chinodoxa, Corylus, Crocus, Erica, Forsythia, Lamium purpureum, Mercurialis perennis, Taraxacum type, Tulipa, Ulex.	Fragaria, Lamium purpureum, Oxalis, Rannunculus, Rubus idacus, Scilla, Syringa, Tulipa, Umbelliferae, Veronica.	Anchusa. Armeria, Aster type, Buddleia, Calystegia sepium, Campanula, Centaurea cyanus, Centaurea nigra, Cerastium, Cistas, Clarkia elegans, Convolvulus arvensis, Cornus, Cucurbito pepo, Epilobium hirsutum, Eschscholtzia, Geranium, Gramineae, Hydrangea, Ilex, Knautia, Ligustrum, Linum, Lonicera, Lotus corniculatus, Lupinus, Lythram salicaria, Melilotus, Papaver orientale, Papaver (shirley poppy), Pinus, Plantago, Rumex, Salvia, Symphoriocarpus, Tillia, Umbelliferae, Veronica, Viola tricolor.	Anemone japonica, Bryonia dioca, Centaura cyanus, Epilobium angustifolium, Gladiolus, Nasturtium, Papaver (shirley poppy).

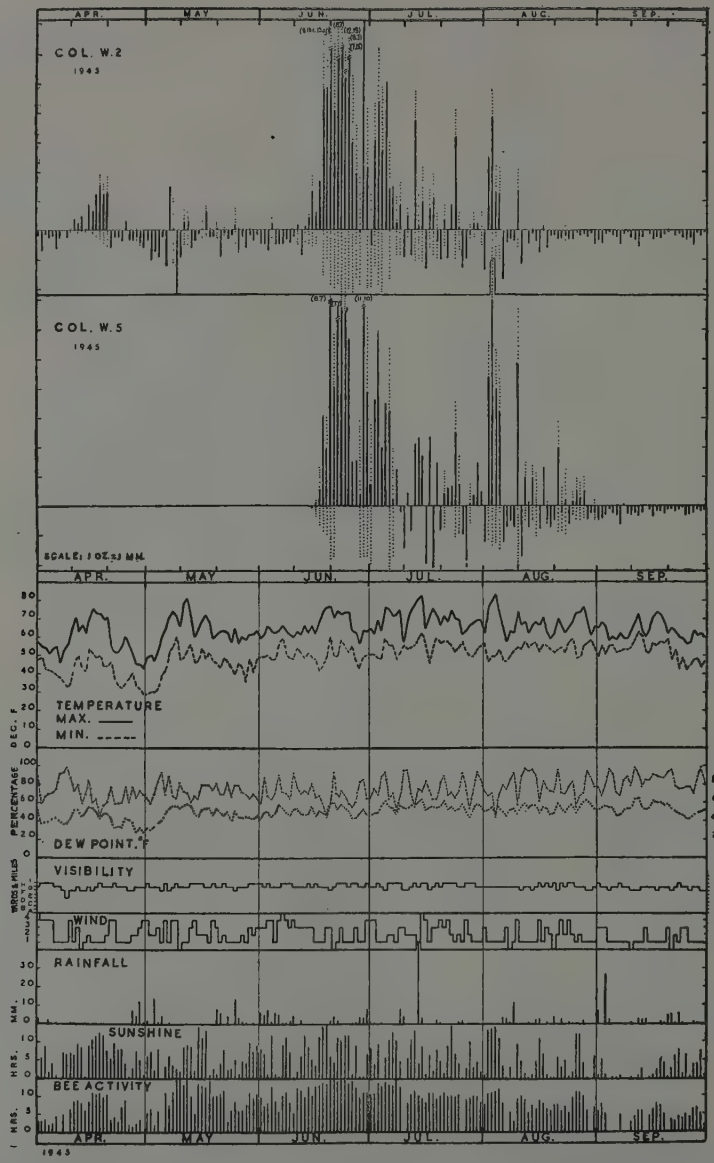

Fig. 1 : Daily changes in weight (colonies W. 2 and W. 5), daily hours of flighting and various weather conditions (1945).

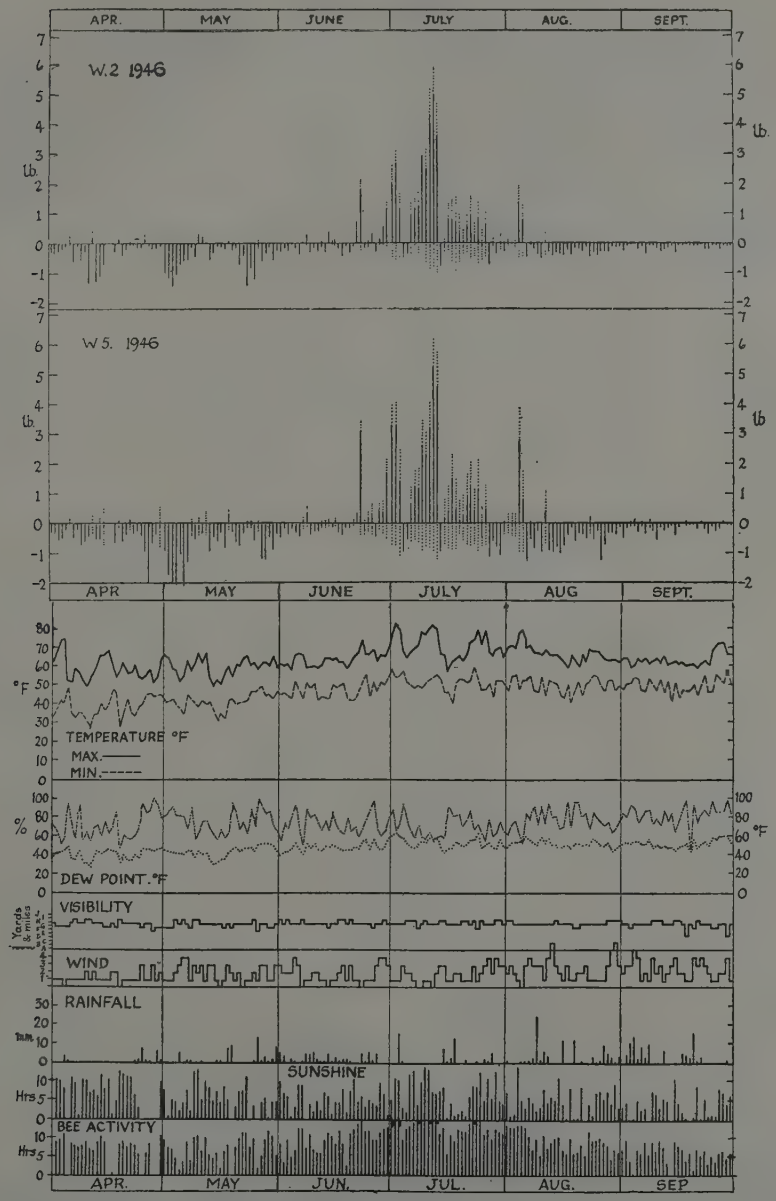

Fig. 2 : Daily changes in weight (colonies W. 2 and W. 5), daily yours of flighting and various weather conditions (1946).

CORRELATION

The method of direct correlation is one of the best method of determining the relationship between changes in colony weight of hours or flighting and weather factors involved, and at least represents a considerable advance over the method of estimating these relationships by inspection of a graph. The correlation coefficients between the various factors were calculated by means of the usual formula. The true or partial correlation is not always the same as the direct correlation, owing to the fairly high correlation between the weather factors themselves.

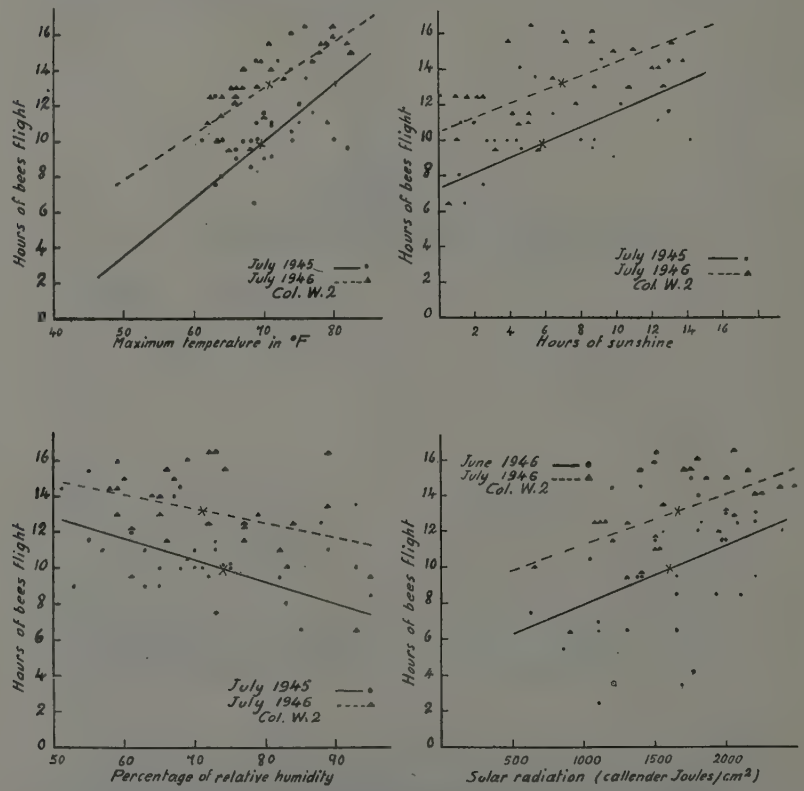

Fig. 3 : Scatter diagrams and regression lines showing relationship between hours of flighting and some weather factors.

DATA EXAMINED

All days irrespective of gain or loss in colony weight are included in the calculations. The correlations have been calculated from the average of each

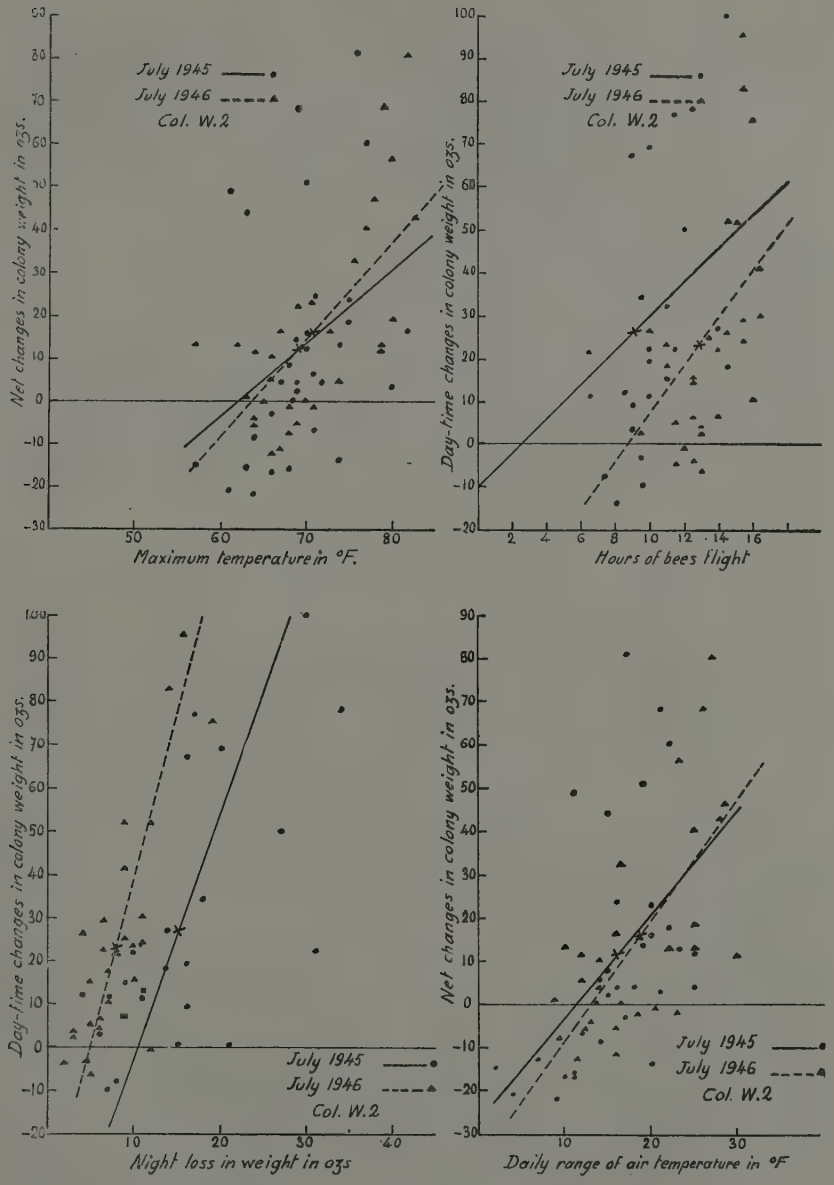
July 1945
July 1946
Col. W.2
Net changes in colony weight in ozs.
Maximum temperature in °F.
Day-time changes in colony weight in ozs.
Hours of bees flight
Night loss in weight in ozs
Daily range of air temperature in °F

Fig. 4 : Scatter diagrams and regression lines showing relation of : maximum temperature × net changes in weight; hours of flighting × daytime changes in colony weights; daytime changes in colony weight × night loss in weight; and daily range of air temperature × net changes in colony weight (July 1945 and 1946).

TABLE II

Interrelation of various weather factors (after Williams, 1940)

	Maximum Temperature	Minimum Temperature	Minimum G.M.	Sun	Relative Humidity	Day Rainfall	Night Rainfall	Cloud	Wind
Minimum temperature	+								
Minimum temper. — G. minimum	+	? −							
Sunshine	+	? −	+						
Relative humidity	−	−	?	−					
Day-time rainfall	−	−	−	−	+				
Night rainfall	−	+	−	+	+	?+			
Cloud	−	+	−	?−	+	+	+		
Wind	?+	+	?−	?−	?	?+	?+	+	
Barometer (level)	?	+	?	+	−	−	−	−	−

+ indicates that the two factors rise, fall together; − indicates that as one increases the other decreases.

TABLE III

Correlations and regressions between the monthly mean of the important weather factors and the monthly mean changes in colony weight or the monthly mean hours of flighting, also between the monthly mean hours of flighting (independent variable) and the monthly mean changes in colony weight — based on departure from the yearly mean of the monthly means (19 years period).

VARIABLES	CHANGES IN COLONY WEIGHT PER DAY IN OZS.			DAILY AVERAGE HOURS OF FLYING ACTIVITY		
	D.F.	COR.	REG.	D.F.	COR.	REG.
Monthly mean maximum temperature in °F	A 11	0.61x	0.35	a 11	0 91xx	0.28
Monthly mean minimum temperature in °F	B 11	0.61x	0.46	b 11	0.86xx	0.35
Monthly mean air mean temperature in °F	C 11	0.61x	0.40	c 11	0.89xx	0.31
Monthly mean daily air temperature in °F	D 11	0 52x	1 003	d 11	0.87xx	0 90
Monthly mean rainfall (inch) per day	E 11	− 0.14	− 46.90	e 11	− 0.55xx	− 61.17
Monthly mean rainy days	F 11	− 0.36	− 27 11	f 11	− 0.67xx	− 27 02
Monthly mean sushinh ours per day	G 11	− 0.55x	1.70	g 11	0.93xx	1.57
Hours of flying activity per day	H 11	0.82xx	1.52	h 1		

x = significant; xx = highly significant.

TABLE IV

Correlations and regressions of the weekly mean changes in colony weight or hours of flighting on some of the main weather factors; also of changes in colony weight on hours of flighting (independent variable), based on departure from the yearly mean of the weekly means during 1945 *and* 1946.

INDEPENDENT VARIABLES	DEPENDENT VARIABLES					
	Weekly average gain or loss in colony weight					
	1945			1946		
	D. F.	COR.	REG.	D. F.	COR.	REG.
Weekly mean maximum temper. in °F	A 51	0.33xx	0.50	38	0.40xx	0.34
Weekly mean air temperature in °F	B 51	0.29x	0.51	38	0.40xx	0.38
Weekly mean ground temperature (1 °F)	C 51	0.32xx	0.58	38	0.43xx	0.43
Weekly mean hours of sunshine per day	D 51	0.49xx	3.44	38	0.37xx	1.56
Weekly mean total rainfall (8 inches)	E 51	−0.06	−1.94	38	−0.08	−1.73
Weekly mean hours of flying activity	F 51	0.50xx	2.14	38	0.44xx	1.02
	Weekly average hours of flying activity					
	1945			1946		
	D. F.	COR.	REG.	D. F.	COR.	REG.
Weekly mean maximum temper. in °F	a 51	0.84xx	0·30	38	0.91xx	0.33
Weekly mean air temperature in °F	b 51	0.81xx	0.33	38	0.88xx	0.36
Weekly mean groud temperature (1 °F)	c 51	0.82xx	0.35	38	0.88xx	0.38
Weekly mean hours of sunshine per day	d 51	0.76xx	1.25	38	0.71xx	1.28
Weekly mean total rainfall (8 inches)	e 51	−0.02	−0.15	38	0.02	0.16

month throughout the years 1927-1946; the weekly mean throughout the year 1945 and up to the end of September 1946; and also for June and July 1945 and 1946 (1). Thus Table III gives the correlations and regressions between monthly means of various weather factors and hours of flighting and weight change, and also the relation between the latter factors.

Table IV gives the correlations and regressions as above but from weekly mean.

Table V gives the correlations and regressions between various weather factors and hours of flighting and also between the latter factor and changes in weight based on departure from monthly mean.

Table VI gives the correlations and regressions between various weather factors and daytime changes in weight or changes in weight over 24 hours, based on departure from monthly mean.

(1) The full calculated data are so bulky to be recorded here, but copies are available for inspection at the Bee Department at Rothamsted.

TABLE V

Correlation and regression of hours of flighting on some of the main weather factors and also daytime changes in colony weight on hours of flighting (independent variable) during June and July (Honeyflow. Colonies W.2 and W.5), 1945 and 1946, based on departure from monthly mean (few results omitted).

MONTH	1945						1946					
	COLONY W. 2			COLONY W. 5			COLONY W. 2			COLONY W. 5		
	D.F.	COR.	REG.	D.F.	COR.	REG.	D.F.	COR.	REG.	D.F.	COR.	REG.
A. Maximum temperature °F. X Hours of flying activity.												
June	29	0.49xx	0.22	—	—	—	29	0.74xx	0.61	29	0.75xx	0.60
July	30	0.56xx	0.32	30	0.48xx	0.27	30	0.74xx	0.26	30	0.79xx	0.28
B. Mean air temperature in °F. X Hours of flying activity.												
June	29	0.49xx	0.39	—	—	—	29	0.59xx	0.53	29	0.57xx	0.49
July	30	0.23	0.17	30	0.25	0.18	30	0.73xx	0.33	30	0. xx	0.31
C. Daily range air temperature in °F. X Hours of flying activity.												
June	29	0 37 x	0.21	—	—	—	29	0.35x	0.26	29	0.57xx	0.41
July	30	0.77xx	0.47	30	0.66xx	0.40	30	0.41xx	0.17	30	0.49xx	0.21
D. Ground temperature in °F. (1 foot) X Hours of flying activity												
June	29	0.63xx	0.90	–	—	—	29	0.52xx	0.67	29	0.48xx	0.59
July	30	– 0.27	9 48	30	– 0.28	– 0.48	30	0.19	0 16	30	0.19	0.17
E. Radiation (Callender-Jules/cm²) X Hours of flying activity.												
June	29	0.42xx	0 0023	—	—	—	29	0.42xx	0.0032	29	0.49xx	0.0035
July.	27	0.72xx	0.0046	27	0.62xx	0.0039	30	0.55xx	0.0028	30	0.56xx	0.0029
F. Sushine hours X Hours of flying activity.												
June	29	0.40xx	0.29	—	—	—	29	0.31x	0.35	—	—	—
July	30	0.53xx	0.43	—	—	—	30	0.69xx	0.38	—	—	—
G. Dew point in °F (9 a. m.) X Hours of flying activity.												
June	29	0.08	0.05	—	—	—	29	0.27	0 20	29	0.18	0.13
July	30	– 0.06	– 0.04	30	– 0.12	– 0.08	30	0.49xx	0.22	30	0.43xx	0.19
H. Relative humidity percentage (9 a. m.) X Hours of flying activity.												
June	29	– 0.44xx	– 0.12	—	—	—	29	– 0.35x	– 0.10	29	– 0.40xx	– 0.11
July	30	– 0.45xx	– 0.12	30	– 0.48xx	– 0.12	30	– 0 .38x	– 0.08	30	– 0.42xx	– 0.09
I. Rainfall 6 a. m. - 6 p. m. (inch) X Hours of flying activity.												
June	29	– 0.35x	– 15.10	—	—	—	29	– 0.36x	– 16.60	29	– 0.45xx	– 19.79
July	30	– 0.84xx	– 36.87	30	– 0.93xx	– 39.86	30	– 0.35x	– 32.75	30	– 0.35x	– 33.37
J. Barometric pressure at noon (inch) X Hours of flying activity.												
June	29	0.20	0.04	—	—	—	—	—	—	—	—	—
July	—	—	—	—	—	—	—	—	—	30	0.70xx	0.07
K. Hours of flying activity X Daytime gain or loss in colony weight in ozs.												
June	27	0.68xx	11.50	—	—	—	29	0.45xx	1.16	29	0.45xx	1.82
July	24	0.51xx	4.37	10	0.60x	9.91	29	0.52xx	5.61	30	0 52xx	6.41

x = significant: xx = highly significant.

Table VI

Correlations and regression of changes in colony weight over 24 hours period or during daytime on some of the main weather factors during June and July (Honeyflow. Colonies W.2 and W.5), 1945 and 1946 (few results omitted), based on departure from monthly mean.

MONTH	1945						1946					
	COLONY W. 2			COLONY W. 5			COLONY W. 2			COLONY W. 5		
	D.F.	COR.	REG.	D.F.	COR.	REG.	D.F.	COR.	REG.	D.F.	COR.	REG.
A. Maximum Temperature in °F X Changes in colony weight in ozs.												
June	29	0.58xx	3.90	—	—	—	29	0.66xx	1.33	29	0.67xx	1.95
July	30	0.36x	1.69	30	0.29x	1.50	30	0.69xx	2.34	30	0.68xx	2.62
B. Maximum Temperature in °F. X Daytime gain or loss in colony weight in ozs.												
June	27	0 63xx	4.55	—	—	—	29	0.65xx	1.40	—	—	—
July	24	0.25	1.32	—	—	—	29	0.76xx	3.23	—	—	—
C. Mean air Temperature in °F. X Changes in colony weight in ozs.												
June	29	0.68xx	8.30	—	—	—	29	0.58xx	1.28	29	0.57xx	1.82
July	30	0.18	1.08	30	0.11	0.72	30	0.53xx	2.35	30	0.54xx	2.72
D. Daily range air Temperature in °F. X Changes in colony weight in ozs.												
June	29	0.8xx	4.16	—	—	—	29	0.20	0.37	29	0.25	0.66
July	30	0.47xx	2.38	30	0.43xx	2.43	30	0.69xx	2.84	30	0.65xx	3.02
E. Ground Temperature in °F. (1 foot) X Changes in colony weight in ozs.												
June	29	0.77xx	16.71	—	—	—	29	0.49xx	1.54	19	0,46xx	2.08
July	30	—0.22	—3.22	30	—0.43xx	—7.01	30	0.38x	3.21	30	0.28	3.00
F. Radiation (Callender-Joules/cm²) X Changes in colony weight in ozs.												
June	29	0 29	0.025	—	—	—	29	—0.03	—0.001	29	0.03	0.001
July	27	0.27	0.014	27	0.35x	0.021	30	0.20	0.010	30	0.15	0.008
G. Radiation (Callender-Joules/cm²) X Daytime gain or loss in colony weight in ozs.												
June	—	—	—	—	—	—	29	0.05	—0.0009	29	0.01	0.0003
July	—	—	—	—	—	—	30	0.16	0. 008	30	0.15	0.0096
H. Sunshine hours per day X Changes in colony weight in ozs.												
June	29	0.32x	3.49	—	—	—	29	—0.15	—0.42	—	—	—
July	30	0.24	1.61	—	—	—	30	0.29x	1.60	—	—	—
I. Sunshine hours per day X Daytime gain or loss in colony weight in ozs.												
June	27	0.44xx	5.57	—	—	—	29	—0.14	—.041	—	—	—
July	24	0.37x	3.04	—	—	—	29	0.28	1.68	—	—	—
J. Dew point in °F. (9 a.m.) X Changes in colony weight in ozs.												
June	26	0.39x	3.84	—	—	—	29	0.49xx	0.87	29	0.47xx	1.20
July	30	0.12	0.63	30	—0.02	—0.10	30	0.46xx	1.99	30	0.58xx	1.84
K. Relative humidity percentage (9 a. m.) X Change in colony weight in ozs.												
June	29	—0.25	—1.01	—	—	—	29	0.01	0.009	29	0.01	0.010
July	30	—0.08	—0.18	30	0.07	0.16	30	—0.32x	—0.65	30	—0.26	—0.60

TABLE VI (continued)

MONTH	1945						1946					
	COLONY W. 2			COLONY W. 5			COLONYW. 2			COLONY W. 5		
	D.F.	COR.	REG.	D.F.	COR.	REG.	D.F.	COR.	REG.	D.F.	COR.	REG.
L. Rainfall 6 a.m. - 6 p.m. (inch). X Daytime gain or loss in colony weight in ozs.												
June	27	−0.18	−135.15	—	—	—	29	−0.20	−24.26	29	−0.15	−26.02
July	24	−0.31	−115 48	—	—	—	29	−0.06	−62.79	30	−0.03	−33.47
M. Barometric pressure (at noon-inch). X Changes in colony weight in ozs.												
June	29	0.18	0.49	—	—	—	—	—	—	—	—	—
July	—	—	—	—	—	—	—	—	—	30	0.32	0 33
N. Barometric pressure (at noon-inch). X Day-time gain or loss in colony weight in ozs.												
June	27	0.27	0.89	—	—	—	—	—	—	—	—	—
July	—	—	—	—	—	—	—	—	—	30	0.28	0.33

The conclusions drawn are :

(1) The similarity of the results obtained from the two colonies indicates that the data are reliable.

(2) That weather factors under consideration have greater influence upon periods of flighting than on changes in colony weight.

(3) The variation in the value of the regression from month to month and from year to year is considerable.

(4) There is a close relationship between period of flighting and changes in colony weight, which will be discussed below.

WHAT IS THE GAIN IN COLONY WEIGHT ?

The net gain in colony weight in any day is an increase in weight of a particular colony of honeybee due to the external activity of bees in gathering nectar, pollen, water, propolis and the internal activity such as the increase due to normal development and wax secretion minus the loss due to evaporation, food consumed for maintenance and dead bees. The food gathering depends on working power and food sources. The working power depends on the gathering ability of the honeybee, the number of field bees, and the duration of working time. The duration of working time depends entirely on weather factors. Food sources depend on the number of plants, age, and environmental conditions.

According to Eckert (1942) and Synge (1946) all colonies do not work on the same source of supply in a given locality. This is immediately evident by an examination of each day's harvest from different pollen traps. The bees may not work on the same sources on different days or even on different trips.

If the day is cold the majority of bees will be confined to the hive and, the gain will be small or negative. If the day is warm there will be greater activity and a correspondingly greater gain.

If on the other hand, the activity of honeybee is the same on two days but the available food in the district is different, then again the gain will alter.

The gain is therefore made up of portions due to the effect on flying activity and honey plants of the different environmental factors plus a portion determined by the total duration of flying activity and food available.

NIGHT LOSS IN COLONY WEIGHT

According to Dalton (1932) evaporation during a honey-flow results in the loss of one-third to one-half of each day's gains the following night. Hambleton (1925) obtained 0.41 correlation between day time gain and following night loss during spring honeyflow but found that the loss on the second night was much less. He claimed that the greater part of the necessary evaporation was accomplished during the first night. Park (1924) stated that although evaporation took place as soon as nectar arrived in the hive, the majority of excess water in the nectar evaporated during the first day and that further evaporation continued for about 3 days.

Table VII

Changes in colony weight during day and night-time of colonies W.2 and W.5 recorded in 6 successive days at Rothamsted in July 1946.

DATE	COLONY W. 2		COLONY W. 5	
	Gain or loss in weight in ozs. in active period	Loss in ozs. during inactive period	Gain or loss in weight in ozs. in active period	Loss in ozs. during inactive period
11th.	83	14	65	13
12th.	95.5	15.5	99	15
13th.	75.5	19	92	19
14th.	— 0.5	12	— 2.5	12.5
15th.	4	6	14	11
16th.	21.5	8	21	13

Table VII gives an example of day's gains and loss in colony weight during night-time in 6 successive days with one unfavourable day, and shows that in this instance the gains of 11-13 July must have given rise to losses until at least 15 July.

Table VIII gives the correlations and regressions between night-time loss

TABLE VIII

Correlations and regressions between night loss and daytime gain or loss in colony weight at Rothamsted.

DATE	1945			1946					
	COLONY W. 2			COLONY W. 2			COLONY W. 5		
	D.F.	COR.	REG.	D.F.	COR.	REG.	D.F.	COR.	REG.
June . .	27	0.95xx	0.23	29	0.52xx	0.06	29	0.77xx	0.10
July . .	24	0.67xx	0.18	29	0.76xx	0.13	30	0.71xx	0.08

xx = highly significant.

and day-time gain or loss in colony weight during honeyflow (June and July 1945-1946) at Rothamsted calculated from departure from monthly mean.

The coefficient of correlation ranging from 0.67 to 0.95. According to data in Table VIII colony W.2 in June 1945 lost during the nights 23 % of the amount gained and during July 1945 lost 19 % of the total gain. The nightly losses of colonies W.2 and W.5 in June 1946 were 6 and 10 % respectively from their gross gain in daytime and 13 to 8 percent during July 1946. The variation occurred from month to month and from year to year in the regression of night loss on daytime gain may be due to the nature of nectar collected. As nectar collected from different sources and under different environmental conditions, is known to have different concentrations and water content.

Hambleton (1925) stated that temperature and relative humidity have little influence on night time loss in weight.

At Rothamsted the correlation coefficient between the percentage of night loss to day's gain in colony weight and minimum temperature as an index to night temperature were 0.07 and -0.25 from colony W.2 and W.5 respectively during July 1946.

THE RELATIONSHIP BETWEEN HOURS OF FLYING ACTIVITY AND CHANGES IN COLONY WEIGHT

From data given in Tables III (H), IV (F) and V (K), it is apparent that there is a highly significant positive correlation between numbers of hours flying activity and changes in colony weight. The correlation found is higher than those between changes in colony weight and any of the other factors, from which it would appear that changes in weight must depend to a large extent on the time the bees spend working on food sources.

From a direct comparison of the histograms of number of hours of flying activity and the histograms of the gain or loss in colony weight in Figs. 1 and 2, a close relationship is found during the period from April to September of the years 1945 and 1946. Every peak that appears in the curve of flying activity coincides with a peak referring to loss in weight during the dearth, or to a gain during the flow period. But it is also evident in this connection that even during the honeyflow period long periods of activity do not always bring about large gains in colony weight. This becomes clear from the data presented in Table IX showing the hours of flying activity and the daily gain or loss recorded on certain particular days during 1945 and 1946 from colonies W.2 and W.5.

TABLE IX

Examples of days selected from the records to show that longer periods of flying activity do not always mean larger gains in colony weight in 1945 *and* 1946.

DATE	1945							
	COLONY W. 2				COLONY W. 5			
	Hours of activity	Daytime gain or loss in ozs.	Night time loss in ozs	Net gain or loss in ozs.	Hours of activity	Daytime gain or loss in ozs.	Night time loss in ozs.	Net gain or loss in ozs.
June 23rd . . .	15	207	42	165	15	—	—	157
June 24th . . .	15 5	127	44	83	15.5	—	—	79
July 11th . . .	8.5	12	4	8	8	9	3	6
July 20th . . .	9.5	− 10x	7	− 17	10.5	− 6	8	− 14
August 11th . .	10.5	− 15	4	− 19	9.7	− 15	13	− 28
August 27th . .	11	− 2	1	− 3	11.5	13	8	5
	1946							
June 25th . . .	12	3.5	2	1.5	12	7.5	4	3.5
June 26th . . .	9.5	7	1.5	5.5	9.5	11	5.5	5.5
July 13th . . .	16	75.5	19	56.5	15.5	92	19	73
July 14th . . .	12	− 0.5	12	− 12.5	11	− 2.5	12·5	− 15
August 4th . . .	13	35.5	8	27.5	14	61	15	46
August 5th . . .	13	20	7	13	14	28	15	13

Minus sign (−) refers to a loss in colony weight

It will be seen from Table IX that in spite of the slight increase in the number of hours flying activity recorded on June 24th 1945 the net gain recorded was about half that on 23rd June 1945. On the other hand a lower activity recorded on June 26th 1946 brought about a larger gain than that

recorded on 25th June 1946. Comparing July 20th and July 11th 1945 one will see that the greater activity on the 20th was accompanied by a loss in colony weight, the opposite is the case with the two days July 13th and 14th of 1946 when higher flying activity on the 13th was associated with a remarkable gain. It is worthy of note that the loss in the daytime on 14th July 1946 was smaller than the loss due to evaporation and colony maintenance during the following night. The large amount of night loss after such a day, which is not infrequent, is probably due to continued evaporation of water from accumulated quantities of nectar stored during the previous few days. Another interesting piece of evidence from Table IX is that on the 4th and 5th August 1946 the number of hours of flying activity were equal but the net gain on these two particular days differed. It seems that great activity evident on a day of little or no gain, may be due to the bees flying out over long distances and for several hours without securing surplus food.

Table III (H) gives the correlation coefficient that exists between changes in weight and number of hours of flying activity, 0.82, and the regression of changes in weight on hours of flying activity, being 1.52 ounces per one hour flying activity. This means theoritically that under Rothamsted conditions the average gain in colony weight is increased by 1.52 ounces per day for every extra hour's flying per day activity over the average then based on monthly means.

With the calculation based on weekly means (Table IV (F)) during 1945 and 1946 the correlation coefficients were 0.50 and 0.44 and the regressions were 2.14 and 1.02 ounces per hour of flying activity respectively. The mean of the two regressions is almost exactly the same as the one above based on monthly means.

For individual honeyflow months, hours of flying activity and daytime changes in colony weight were found to have positively highly significant correlations ranging from 0.45 to 0.68 in June and July 1945 (colony W.2) and June and July 1946 (colonies W.2 and W.5). The only just significant correlation, 0.60, obtained during July 1945 (colony W.5) may be due to the small number of observations used. The regressions of daytime changed in colony weight on number of hours of flying activity for the same months ranged from 1.16 to 11.5 ounces per hour flying activity Table V (K) (notice the higher regressions obtained during months associated with abundance of food). Under the conditions of June 1945 one hour flying activity above the average added 11.5 ounces to the average daytime gain in weight.

In conclusion, a close relationship exists between hours of flying activity and changes in colony weight. The regression of changes in colony weight on number of hours flying activity is more constant over longer periods. Variation in the regressions in individual months is observed and must be due to other factors than those influencing the two variables simultanously.

TEMPERATURE

Temperature has a profound effect upon bees in many ways. The extremes of temperature limit the activities of bees although honeybees because of their ability to generate and conserve heat have a wide ecological distribution.

Changes in temperature constitute stimuli to which honeybee react, tending to choose an optimun condition. Temperature has an important effect on the reactions of bees to other stimuli.

Results

The relationship (during June and July 1945 and 1946) between maximum temperature and daily net changes in colony weight for colonies W.2 and W.5 is shown in Table X. The maximum temperature has been divided into 5°F. intervals and each day's gain is assigned to its appropriate class. The average for each class is then found for each colony in each year, for both colonies in each year, and finally for both colonies over the two years.

The optimal temperature for nectar gathering

The final averages at the bottom of Table X are represented by the

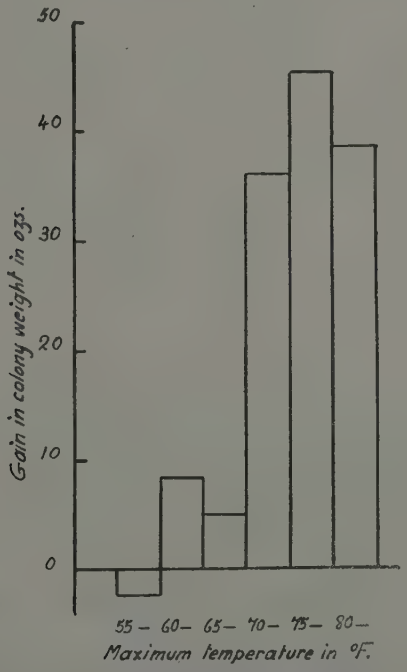

Fig. 5 : Histogram showing the optimal temperature for nectar gathering.

histogram in Fig. 5. It may be seen that the lowest range of maximum temperature at which colonies of honeybees gained in weight during the honeyflow period was 60-64°F. The highest temperatures recorded in the period were in the group 80-84°F. At this level there was also a gain in weight. The optimum temperature or the temperature at which the greatest average gain in colony weight was recorded for the two years 1945 and 1946 was between 75 and 79°F. where an average gain of 45.13 ozs. per day was recorded.

TABLE X

Summary of computation of group averages to indicate relation between maximum temperature and net daily gains in colony weight at Rothamsted, 1945-1946 (June and July).

Colony	55 - 59 °F weight in ozs.	60 - 64 °F weight in ozs.	65 - 69 °F weight in ozs.	70 - 74 °F weight in ozs.	75 - 79 °F weight in ozs.	80 - 84 °F weight in ozs.
1945						
W. 2	— 8.3	10.6	5.9	47.5	61.8	9.5
W. 5	— 8 5	33.2	14.2	44.4	41.8	33.0
Total	— 16.8	43.8	20.1	91.9	103.6	42.5
Mean	— 8·4	21.9	10.05	45.95	51.8	21.25
1946						
W. 2	0.31	— 0.62	2.6	11.75	38 5	47.33
W. 5	—0.75	—1.15	1.63	12.08	40.29	53.16
Total	—0.44	—1.77	4.23	23.83	78.79	100.49
Mean	—0.22	— 0.89	2.12	11.92	39 4	50.25
Mean 1945-1946	—2.17	8.41	4.97	36.2	45.13	38.65

It will be noted also from the shape of the curve in Fig. 5, that a lowering of the temperature from 70°F. reduced the rate of gain in colony weight very quickly whilst an increase in temperature above 79°F. decreased gain in colony weight slightly. As we have no records of temperature higher than 86°F. it is not possible to say whether this drop will continue in agreement with the findings of Bodenheimer and Ben-Nerya (1937) in Palestine.

Maximum temperature and changes in weight

The mean regression of changes in weight on maximum temperature for the nineteen years period (Table III (A)) is 0.35 ounces per 1°F, the correlation being 0.61 which is positive and significant.

With the correlation based on weekly mean during 1945 and 1946 (Table IV (A)) the regressions were 0.50 and 0.34 respectively or the average gain in colony weight is increased by an 0.75 to 1 ounce by a rise of 1°F. The correlations between weekly mean maximum temperature and weekly mean changes in colony weight for 1945 and 1946 were 0.33 and 0.40. All the correlations between the two variables were positive and highly significant.

For the months of June and July only maximum temperature and changes in colony weight were found positively correlated with coefficients ranging from 0.29 to 0.69 (colony W.2 and W.5) during the two successive years 1945 and 1946, whilst the regressions of changes in colony weight on maximum temperature during the same months ranged from 1.33 to 3.9 ounces per °F.

For the same period taking only the daytime changes in colony weight, positive highly significant correlation coefficients were found except for July 1945 (colony W.5) where the correlation coefficient was, 0.25, which is positive but not significant. The correlations ranged from 0.25 to 0.75, whilst the regressions ranged from 1.32 to 4.55 ounces per 1°F. Thus for example it seems that for colony W.2 during July 1946 conditions one degree increase in the maximum temperature above the average will add 2.34 ounces to the net gain in weight over the 24 hours but 3.23 ounces to the net daytime gain. The fact worth noting is the variation found when calculating the regressions of these two variables for the various months during the different years due to the fact that the abundance of nectar or pollen influences the production of honey or surplus stores. It is quite clear that in 1945 the bees stored more stores during June than during July, therefore one can easily understand why a rise in the maximum temperature of 1°F. above the average, theoretically, added 3.9 ounces to the average gain over 24 hours in colony weight in June and only 1.69 ounces in July during 1945 (see Table VI (A)). The opposite result was obtained during 1946 when the available food was smaller during June this time than during July.

Maximum temperature and hours of flighting

It will be seen from Tables III (a), IV (a) and V (A), that a positive highly significant correlations were found between number of hours of flighting and maximum temperature without any exception whether the calculation was based on normal monthly means for 19 years, weekly means for each the two years 1945 and 1946, or for individual honeyflow months in two successive years using data of two different colonies W.2 and W.5. The correlations were 0.91 for the monthly means, 0.84 and 0.91 for the weekly means, and for individual months ranged from 0.48 to 0.79. The regression of monthly mean hours of flighting on monthly mean maximum temperature was 0.28 hours per 1°F. This means that, theoretically, about 4°F. rise above

the average maximum temperature will add one hour to the average hours of flighting. There is the same tendency to bigger regressions in June 1945 and July 1946 than in July 1945 and June 1946, that has already been noticed between changes in colony weight and maximum temperature.

DAILY RANGE OF TEMPERATURE

The discussion on the differences in daily range of temperature between days of high and low gain in colony weight made it clear that a sngnificant relation would be found.

Daily range of temperature and changes in weight

It will be seen from Table III (D) that a positive significant correlation coefficient, 0.52, exists between the normal daily range of air temperature and the normal change in colony weight. The regression of changes in colony weight on daily range of air temperature was 1.003 ounces per 1°F. or an increase of 1°F. above the normal daily range may add one ounce to the average gain in weight. It is interesting to note that the regression obtained is two or three time greater than that obtained for changes in colony weight on maximum, minimum, and mean air temperatures. This is probably due to the smaller variability of the daily range.

For individual months during the honeyflow period (Table VI (D)) the correlations between daily range and changes in weight were positive and highly significant during June and July 1945 and July 1946, ranging from 0.43 to 0.69, and positive but not significant, during June 1946 (0.20 to 0.25) in which month sunshine was below average and rainfall above average. The regressions of changes in weight during the two successive years in June and July on daily range varied from 0.37 to 4.16 ounces per °F. Therefore, a rise of 1°F. in daily range in June 1945 would give an increase of 4.16 ounces above the average gain in weight.

Daily range of temperature and number of hours of flighting

Table III (d) gives the correlation and regression between the normal monthly mean number of hours of flighting and the daily range. The correlation, 0.87, was positive and highly significant. So under Rothamsted conditions 1°F. rise above the normal daily range would add to the average flighting period 0.9 hours or roughly one hour.

Regarding the honeyflow months, it will be seen from Table V (C) that remarkable positive and highly significant correlation coefficients were nearly always found, ranging from 0.35 to 0.77. The regressions of number of hours of flighting on daily range varied from 0.17 to 0.47 hours per 1°F. For example, according to these data, in July 1945 about 2.5 °F. increase above

the average daily range in air temperature would be associated with an increase in the period of flighting of approximately an hour above the average.

GROUND TEMPERATURE

Soil temperatures are included in view of the interest which has recently been taken in them although the literature contained unsufficient information about their influence upon bee behaviour.

Results

Ground temperature at one foot depth has been taken as the most suitable index.

Ground temperatures and changes in weight

The correlation coefficients found during 1945 and 1946 based on weekly means were 0.32 and 0.43, and the regressions of changes in weight on ground temperature were 0.58 and 0.43 ounces per 1°F. Thus a high ground temperature was associated with increased colony gains (Table IV (C)).

For individual months of the main honeyflow correlations between ground temperature and changes in weight were found (Table VI (E)) to be positive and highly significant during June in 1945 and 1946, with a range from 0.46 to 0.77 whilst the regressions of changes in weight on ground temperature were 16.71 and 1.54 ounces per 1°F. respectively. But during July 1945 the correlations found, -0.22 (colony W.2) and -0.43 (colony W.5) were negative though not significant for the former colony, but both were high enough to emphasis the influence and the trend. In July 1946 the correlations were positive but only significant for data belonging to colony W.2 and not significant for colony W.5. It seems that ground temperature as a factor influencing growth and connected with the root system of the plants has an important influence on plant behaviour, which is reflected in the changes in colony weight. From the regressions presented in Table IV (C) one could say theoretically that 1°F. rise above the average will increase the gain in colony weight by 0.43 to 0.58 ounces above the average gain per day. It may be that during the period when the plants have largely ceased to grow actively, but are still flowering, ground temperature has a relatively minor effect on the changes in colony weight and that sometimes high ground temperature, as indicated by the negative correlations obtained during July 1945 and supported by the lack of significance of the positive correlation of July 1946, must be regarded as an unfavourable factor. The effects of ground temperature, if any, are likely to be very different on different crops, e.g. clover and lime.

Ground temperatures and number of hours of flighting

Ground temperature has no direct influence on bees, but flying, like colony gain, may be influenced indirectly through nectar secretion. Highly significant correlations were found between ground temperature and hours of flighting during the same periods as already mentioned above (Tables IV (c) and V (D), June 1945 and 1946). Ground temperature depends upon the amount of heat the ground absorbs during the previous day and the amount of cloud during the night which affects radiation. To obtain conclusive evidence of the effect of ground temperature as such it would be necessary to make an anlysis of partial correlations, in order to exclude the effect of air temperature, but it has not been possible to extend this study so far.

SOLAR RADIATION AND SUNSHINE

Results at Rothamsted showed clearly that flighting in the summer is not confined to the hours of sunshine. In June, July and August 1945 there were 335.5, 300.8 and 237.8 (average of colonies W.2 and W.5) hours of flighting, but only 200.9, 181.1 and 147 hours of sunshine, and in the same three months of 1946 the figures were 294.5, 408.5 and 288 hours of flighting and 155.2, 215.5 and 151 hours of sunshine respectively.

Solar radiation and changes in weight

The total radiation measured by a Callender recorder at the Physics Dept., Rothamsted were studied.

With the exception of the one month July 1945 no significant correlations were obtained between total radiation and changes in colony weight during the months of honeyflow period, either with net gain of the whole day or daytime net gain (see Table VI (F) and (G)).

Solar radiation and hours of flighting

From Table V (E) it is quite clear that a positive and highly significant correlations existed, ranging from 0.42 to 0.72, during June and July 1945 and 1946 between the total radiation (Callender-Joules/cm2) and number of hours of flighting per day. The regressions of hours of flighting on total radiation ranged from 0.0023 to 0.0046 hours of flighting per one Joules/cm2.

Hours of sunshine and changes in weight

The amount of sunshine in relation to daily changes in weight and hours of flighting is shown graphically in Figs. 1 and 2. Slightly over 15 hours of sunshine per day is possible in June and July at Rothamsted whilst 16 hours of flying activity is common during this period. The relation between sun-

shine and daily changes in weight shows variations within months, between months and between years. The low gains that were associated with 0 to 2 hours sunshine would be expected. In some cases rainfall on those days would reduce bee flighting activity.

A correlation, 0.55, existed between monthly mean hours of sunshine per day and changes in colony weight. The regression of changes in colony weight on hours of sunshine was 1.7 ounces per one hour of sunshine (Table III (G)).

From Table IV (D) it will be seen that the correlations during 1945 and 1946, i.e. 0.49 and 0.37, were positive and highly significant. The regressions of changes in colony weight on hours of sunshine based on weekly mean were 3.44 and 1.56 ounces respectively per one hour sunshine.

Regarding individual months during the honeyflow period one can see from Table VI (H) and (I) that positive and significant correlation coefficient of 0.32 and 0.29, existed during June 1945 and July 1946 between hours of sunshine and changes over 24 hours in weight; whilst the correlations with daytime gross gain or loss in colony weight were positive and highly significant in June 1945, significant in July 1945, and positive but not significant in July 1946. During June 1946 there are non-significant and negative correlations. During months when lack of sufficient nectar occured as a result of unfavourable conditions, plenty of sunshine may encourage the bees to commence flighting and consume more food without bringing in surplus stores to balance the loss in weight. The regressions of changes in weight over 24 hours on hours of sunshine ranged from -0.42 ounces to 3.49 ounces per hour sunshine, and for daytime gross gain or loss in weight on sunshine from -0.41 to 5.57 ounces per hour sunshine.

Hours of sunshine and period of flighting

There was a highly significant positive correlation coefficient, 0.93, between hours of sunshine and hours of flighting (Table III (g)) using monthly means. The regression of hours of flighting on hours of sunshine was 1.57 hours per one hour sunshine. The correlations based on weekly means were 0.76 and 0.71 during 1945 and 1946 respectively. The regression of hours of flighting on hours of sunshine were 1.25 and 1.28 hours per one hour sunshine. The results of both years were therefore very similar.

So far as individual months during honeyflow period are concerned, it will be seen from Table V (F) that positive and highly significant correlations were obtained ranging from 0.40 to 0.69 during June, July 1945 and July 1946, and a positive and significant, 0.31, correlation coefficient during June 1946 between hours of sunshine and hours of flighting. The regressions of hours flighting on hours of sunshine ranged from 0.29 hours to 0.43 hours flighting per one hour sunshine.

AIR MOISTURE

Animals living in many different habitats have the chance to select moisture conditions in the same way as they select the conditions of light and temperature which are most suitable for them.

In the present study it was hoped to measure the relationship between changes in colony weight, or duration of flighting, and the amount of water in the atmosphere expressed as « Dew point » which is the temperature at which the particular amount of water in the air is sufficient to produce saturation. Secondly to study the relationship between the former two dependable variables and moisture in connection with temperature as « Relative humidity » which is a measure of the water in the air in proportion to the total amount that would be required to produced saturation. Relative humidity and dew point readings at 9 a.m. are available at Rothamsted. The relative humidity at midnight and after in this locality is nearly always over 90 % even in the summer months. On account of this it was thought that 9 a.m. relative humidity readings might be a suitable index of the character of the day so far as atmospheric moisture is concerned. As thus relationship is measured on the base of the fluctuations occurring from one day to another and we know that dew point is more constant than relative humidity, it was thought that the former might give better information. Although temperature and relative humidity are closely correlated, it would appear that each may influence flighting and changes in colony weight independently.

Dew point and changes in weight

The positive correlation coefficients (Table VI (J)) between dew point °F. and daily changes in colony weight were significant in June 1945 and highly significant during June and July 1946, but there was no correlation found during July 1945. This indicates that the higher the dew point the greater will be the gain in colony weight. The regressions of changes in colony weight on dew point °F. during those months in which a close relationship was found, ranged from 0.87 to 3.84 ounces per °F. dew point.

Dew point and number of hours of flighting

From Table V (G) it will be seen that during the honeyflow period in the two successive years 1945 and 1946 the dew point has practically no relation to flighting, except during July 1946 for which positive and highly significant correlations were found, ranging from 0.43 to 0.49. The regressions of the hours of flighting on dew point °F. in July 1946 ranged from 0.19 to 0.22 hours per 1°F. dew point.

Relative humidity and changes in weight

In the present study correlation coefficients of -0.25 and -0.26 to -0.32 were found between changes in colony weight and the relative humidity at 9 a.m. during June 1945 and July 1946 respectively. In July 1945 and June 1946 practically no correlation between changes in colony weight and relative humidity (see Table VI (K)) was found. Although the correlations existing were not significant, yet June 1945 and July data may indicate that there was a tendency for a dry atmosphere to have a favourable influence on changes in colony weight. The regressions of changes in weight on the relative humidity during those two particular months ranged from -0.60 to 1.01 ounces per one per cent relative humidity.

Relative humidity and hours of flighting

Negative and significant or highly significant correlations were obtained, from -0.35 to -0.48, between hours of flighting and relative humidity at 9 a.m. during June and July 1945 and 1946. The regressions of hours of flighting on relative humidity percentage ranged from -0.08 to -0.12 hours per 1 % change in relative humidity (see Table V (H)). This means, theoretically, that about 10 % reduction in the relative humidity below the average will extend the average duration of flighting one hour beyond the average.

RAIN

Since the rain recorded for the 24 hours may give misleading results if attempts are made to use it in a calculation of the relationship between the behaviour of honeybees and rainfall, the rainfall from 6 a.m. to 6 p.m. (daytime) was obtained from the records.

Rainfall, rainy days and changes in weight

Consideration of Table III (E) and (F) show that if note is taken of the number of rainy days rather than the actual rainfall the negative correlation is greater than that with rainfall. This is presumably because the number of rainy days is a better measure of the hindrance to nectar gathering. The correlation, -0.14, found between rainfall and changes in weight does not mean that rain is not important but simply that in the Rothamsted area, as in most parts of England, the rain is reasonably adequate and distributed evenly throughout the year. The negative correlations support previous workers ideas that excess rainfall or rainy days may have an unfavourable influence on changes in weight. The data of the two years are in agreement (Table IV (E)).

During the honeyflow period, June and July 1945 and 1946, it would

seem from the correlations (Table VI (L)) that rainfall between 6 a.m. and 6 p.m. has an adverse influence on daytime changes in colony weight where negative correlations ranged from -0.03 to -0.31 were found and that the regressions were ranged from 2.6 ounces to 13.5 ounces loss per 0.1 inch increase of rain.

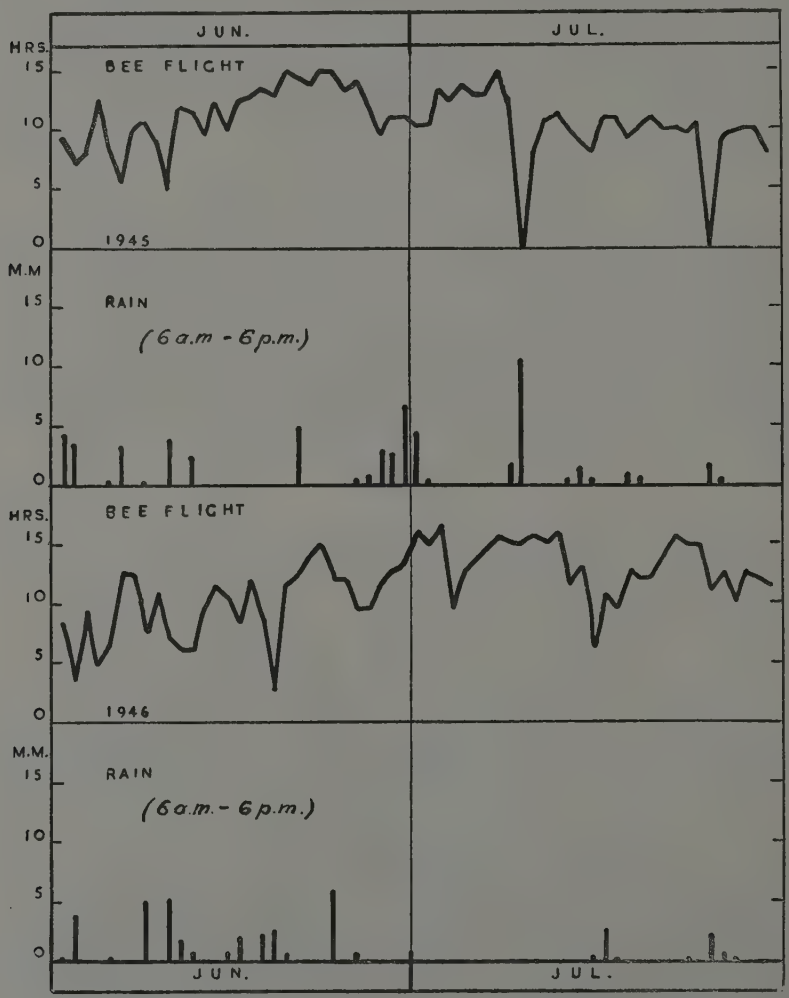

Fig. 6: Curves and histograms showing the relationship between rainfall during the daytime and hours of flighting.

Rainfall, rainy days and hours of flighting

In Table III (e) there is a negative and significant correlation, -0.55, between hours of flighting and rainfall, and the regression was -6.1 per 0.1 inch of rain. Secondly in Table III (f) a negative and highly significant correlation, -0.67, is seen for rainy days, and the regression was -27 per one rainy day. From Table IV (a) it will be seen that no correlation was found during 1945 and 1946 between rainfall and hours of flighting as far as weekly means are conserned. During these two years rainfall was probably relatively unimportant compared with the other environmental factors influencing flying.

The curves and the histograms (Fig. 6) show the close relationship between rainfall during the daytime and hours of flighting.

Analyses of June and July data during 1945 and 1946 showed that the correlation coefficient (Table V (I)) between rainfall (6 a.m. to 6 p.m.) and hours of flighting ranged from -0.35 to -0.84 and that the regressions ranged from 1.5 hours to 4 hours per 0.1 inch of rain.

BAROMETRIC PRESSURE

Data for the atmospheric pressure was obtained from a recording barograph. Bees are diurnal insects, therefore, the barometric reading was that at midday.

The method of Williams (1940) proved to be very satisfactory for the purpose of such analyses and was, therefore, adopted. The days under discussion were divided into nine categories, showing the interrelation of two sets of three factors. First from the point of view of the height of the

TABLE XI

Frequency of occurrence of different barometrical conditions. Top line in June and July of 1945-1946; *bottom line in all four months.*

	RISING				STEADY				FALLING				TOTAL			
High .	2	1	1	1	4	5	—	3	5	2	2	3	11	8	3	7
Total .	5				12				12				29			
Medium	3	7	4	3	9	7	4	5	5	6	5	4	17	20	13	12
Total .	17				25				20				62			
Low .	2	1	7	4	—	1	4	4	—	1	3	4	2	3	14	12
Total .	14				9				8				31			
Total .	7	9	12	8	13	13	9	11	10	9	10	11	30	31	30	31
Total .	36				46				40				122			

barometer the days are divided into those on which the barometric pressure was high, medium and low. A medium barometric pressure was taken to be between 29.9 and 30.2 inches. Secondly, according to the direction of movement the days are divided into those upon which barometric pressure was rising, steady and falling.

In order to show the relation between atmospheric pressure and hours of flighting, gain or loss in colony weight during daytime and the changes in colony weight over 24 hours, the data of June and July were selected in two successive years 1945 and 1946 and were divide into the former nine categories.

Data given in Table XI show the number of days in each of these categories during each month and the total of the two years, which included 122 days. The greatest number of days in any category is 25 in the « medium steady » class and the smallest number is 5 in the « high rising » class.

In all the three cases under examination the departure of the variables from the monthly mean was entered for each day in its proper category. The average departure for the two colonies W.2 and W.5 for the two years was determined.

Barometric pressure and hours of flighting

Table XII shows the effect of barometric pressure on the hours of flighting. It will be seen that the « high falling » barometric pressure gives the greatest number of hours of flighting with an average departure of 1.7 hour above the average, whilst a « low steady » barometric pressure gives the shortest period of flighting with 2.8 hours below the average. Periods of flighting longer than average occurred when the barometric pressure was high and medium, periods shorter than average when the barometric pressure was low and rising, steady or falling.

TABLE XII

Departure of hours of flighting from monthly mean under various barometrical conditions (*June and July* 1945 *and* 1946).

	RISING hours	STEADY hours	FALLING hous	MEAN hours
High .	1.4	0.2	1.7	1.0
Medium .	0.2	0.9	0.2	0.5
Low . .	—1.5	—2.8	—0.5	—1.6
Mean .	—0.3	—0.0	0.5	

If the direction of the movement is neglected, the hours of flighting (from the two years average) with high, medium and low barometric pres-

sures are 1.0, 0.5 and -1.6 hours respectively. If the height of the barometer is neglected the average departures with rising, steady and falling barometric pressures are -0,3 -0.0 and 0.5 hours respectively.

TABLE XIII

Departure of changes in weight during daytime from the monthly mean under various barometrical conditions (June and July 1945 and 1946).

	RISING ozs.	STEADY ozs.	FALLING ozs.	MEAN ozs.
High .	0.6	—2.4	23 3	11.9
Medium .	—12.6	0.8	6.2	—1.3
Low . .	—0.8	—13.0	1.1	—4.0
Mean . .	—5·5	—3.7	9.8	

Barometric pressure and changes in weight

Table XIII shows the departure of the gain in colony weight during daytime from the monthly mean, under various barometrical conditions (June and July 1945 and 1946).

It will be seen that a « low steady » barometric reading is coupled with the lowest daytime gain in colony weight with an average departure of -13 ounces below the average, and the highest daytime gain in colony weight occurs when the barometer is high if falling with an average departure of 23.3 ounces above the average.

If the direction of movement is neglected the mean departure of the gain in colony weight during the daytime under high, medium and low barometric pressure are 11.9, -1.3 and -4.0 ounces respectively. Neglecting the height of the barometer the mean departures with rising, steady and falling barometric pressures are -5.5, -3.7 and 9.8 ounces respectively.

Table XIV shows the effect of barometric pressure on net gain or loss in colony weight during 24 hours in June and July for the two years under consideration.

TABLE XIV

Departure of net gain in weight over 24 hours during the honeyflow season (June-July) from the monthly mean under various barometrical conditions during 1945 and 1946.

	RISING ozs.	STEADY ozs.	FALLING ozs.	MEAN ozs.
High .	—1.3	—4.3	18 5	5.7
Medium .	—10 6	5 4	—0 1	—0.8
Low . .	—2 2	—12.6	1 0	—4.4
Mean .	—6.0	—0.6	5.7	

It will be seen from Table XIV that a « high falling » barometric pressure gives the highest net gain in colony weight with an average departure of 18.5 ounces above the average, whilst a « low steady » barometric pressure gives the lowest net gain in colony weight with an average departure of -12.6 ounces below the average. If the direction is neglected the mean departure of net gain in colony weight (over 24 hours) under high, medium and low barometric pressures are 5.7, -0.8 and -4.4 ounces respectively. Neglecting the height of the barometric pressure the mean departures of net gain in colony weight under rising, steady and falling barometric pressures are -6.0, -0.6 and 5.7 ounces respectively.

Correlation coefficient

The correlations between barometric pressure and hours of flighting per day for June 1945 and July 1946 are given in Table V (J). The correlations obtained were 0.20 and 0.77 respectively and the regressions were 4 and 7 hours per one inch rise in the barometric pressure. June 1945 correlation was not significant but it is probably large enough to indicate a tendency for the longer duration of flighting to be associated with increased barometric pressure whilst in July 1946 a positive and highly significant correlation existed between the two variables which tends to confirm that a positive relationship exists between hours of flighting and barometric pressure.

The correlation between the barometric pressure and the changes in colony weight both during daytime and during a 24 hours period for June 1945 and July 1946 are given in Table VI (M) and (N). In all cases a positive relationship exists although the correlations, 0.18 and 0.32 over 24 hours period and 0.27 and 0.28 daytime period, were not by themselves significant, but can be accepted as index for the tendency. The regressions of changes in colony weight on barometric pressure ranged from 3.3 to 4.9 ounces per 0.1 inch of mercury while for daytime they ranged from 3.3 to 8.9 ounces per 0.1 inch.

WIND

The direction and velocity of the wind plays an important part in determining the weather and the climate of a place and is one of the important controlling factors influencing the behaviour of honeybees.

Wind velocity and direction were obtained at Rothamsted by the use of a Dines anemograph situated on the roof of one of the main buildings of the Institute about 300 yards away to the east from the scale-hives, the vane being about 30 feet above the building and 70 feet high above the ground.

Table XV

Frequency of occurrence of different wind conditions.
Top line in June and July of 1945 and 1946; bottom line in all four months.

FORCE	WIND DIRECTION								TOTAL
	?	N.	NE.	E.	SE.	S.	SW.	W.	NW.	
CALM 0	1 | | 3 | 3 7									1 | | 3 | 3 7
1		2 | 1 | 2 | 1 6	1 | 2 | 2 | 1 6	| | | 1 1	| 1 | | 1	2 | 2 | 1 | 8	2 | 1 | 2 | 2 7	3 | 1 | 3 | 4 11	| 3 | 2 | 5	10 | 11 | 12 | 12 45
2		| 2 | | 1 3	| | | | 	| 1 | | 1	| | | 1 1	| 1 | | 1	| | 3 | 3 6	| 2 | 1 | 2 5	| 2 | 2 | 4	| 8 | 6 | 7 21
3		2 | 1 | | 3	| | | | 	1 | 2 | | 1 4	1 | | | | 1	| | | 1 1	| 2 | 2 | 4	5 | | 3 | 3 11	3 | | 1 | 2 6	12 | 5 | 6 | 7 30
4		| | | | 	| 1 | | | 1	| | | | 	| | | | 	1 | | | | 1	1 | 2 | 2 | 5	3 | 1 | | 1 5	1 | 2 | 1 | 1 5	6 | 6 | 3 | 2 17
5		| | | | 	| 1 | | | 1	| | | | 	| | | | 	| | | | 	1 | | | | 1	| | | | 	| | | | 	1 | 1 | | | 2
TOTAL	1 | | 3 | 3 7	4 | 4 | 2 | 2 8	1 | 4 | 2 | 1 6	1 | 3 | | 2 3	1 | 1 | | 1 11	3 | 3 | 1 | 4 23	4 | 5 | 9 | 5 32	11 | 4 | 7 | 10 20	4 | 7 | 6 | 3 122	30 | 31 | 30 | 31

The vane was in a considerably more exposed position than the scale-hives, and the wind velocities recorded cannot of course be exactly comparable with the velocities which affected the honeybees in their flight near ground level. On the other hand the velocities were recorded within the foraging area of the bees, and they are the nearest available yardstick for comparison.

For purposes of analysis the force and direction of the wind during the daytime were studied. The wind velocity was the maximum observed during each day, and the direction was that most frequently recorded. There were six wind velocities (Beaufort 0-5) and nine wind directions (Nil, N, NE, E, SE, S, SW, W, and NW).

Results

In order to show the relation between wind and hours of flighting and changes in colony weight, the data obtained during June and July (honey-flow) in two successive years 1945 and 1946 were selected.

The method of analysis consisted in placing in the correct categories the value of the hours of flighting and net gain or loss in colony weight for each of the days and finding the average hours of flighting and the average net gain or loss in colony weight for all days in that category each year separately and finding the average for the two years together.

Data given in Table XV shows the number of days in each of these categories for each month and the total of the two years, which included 122 days on which data were examined.

The highest total number of days in one category is 11 days in the « West wind force 1 » class and « West wind force 3 » class; in 11 of these categories there were no records, and only one record is available in a further 11 categories.

Fig. 7, A and a, illustrate graphically the frequency distribution of the days according to the velocity and the direction of the wind in June and July during the two years.

The daily average hours of flighting or the net gain or loss in colony weight was the average from the data of both colonies W.2 and W.5.

Wind and changes in weight

Table XVI shows the average daily net gain or loss in colony weight under various wind conditions.

The mean effect of wind velocity, irrespective of direction, on daily gain or loss in colony weight is shown in the right hand of Table XVI. Calm days produced the maximum daily mean gain 36.9 ounces. Average daily gains of 26.4, 8.1, 11.3, 1.9 and 7 ozs. (based on only 2 records) were pro-

duced by wind scales 1, 2, 3, 4, and 5 respectively. The results, therefore, demonstrate that wind velocity is very detrimental to nectar collection.

TABLE XVI

Changes in weight under different wind conditions during June and July 1945 *and* 1946 (*daily average*).

YEAR	FORCE	WIND DIRECTION									MEAN	2 YEARS MEAN
		CALM	N.	N.E.	E.	SE.	S.	SW.	W.	NW.		
1945	CALM	65									65	36.9
1946		32.3									32.3	
1945	1		29.2	33.5		25	69 8	18.9	57.5	30.3	41.4	26.4
1946			10	4.6	38.5		21.8	15.4	13 4	—2.3	13 3	
1945	2		3.3		47		—14		24 6	10 5	13.7	8 1
1946			18.3			64.8		0	—3.9	—4.3	4 6	
1945	3		6		17.2	111		7.5	39.6	—5	22.3	11.3
1946					9 5		—11.5	8.6	—4	—6.8	—2.3	
1945	4			12			—12	—16.9	—1	32.7	3.6	1·9
1946								3.8	—14.5	—2	—2.2	
1945	5			22				—8			7	7
1946												
1945	MEAN	65	14	26.9	14.6	68	42.1	1.4	31.5	17.7		
1946		32.3	21.1	4.6	24	64.8	15.1	6.2	2.3	—4.2		
2 YEARS MEAN		36.9	13.4	18.5	24.4	66.9	29.8	4.3	16	7.9		

It will be seen that the reduction is remarkable except that the average in group 3 is higher than that of the preceding group and also in group 5 is higher than that of group 4 which may be due to the unequal number of observations recorded in each group.

The results so far as wind direction is concerned are variable and sometimes contradictory. For instance, the six days on which moderate NE. winds were recorded show changes in weight below the average for winds of scale 1 velocity, but the single record for NE. wind of scale 5 shows a gain considerably greater than was expected. Two of the three records for SE winds were associated with very considerable gains in colony weight. NW. winds were fairly consistently associated with gains well below average. The final values for the whole period calculated from 122 days are shown in Fig. 7, B and b.

Wind and honeybee flighting

Table XVII shows the effect of wind on the hours flighting and Fig. 7, C and c, illustrate the relation between the length of the flighting period

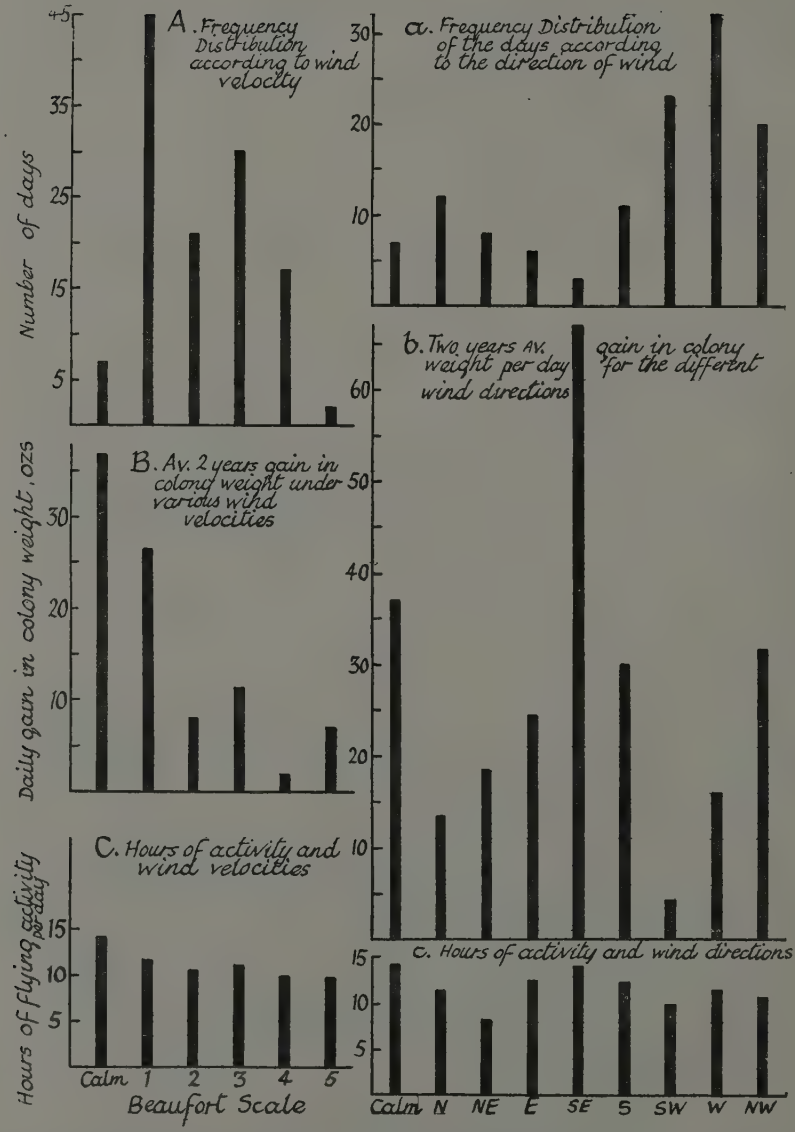

Fig. 7 : Diagrams showing the relationship between wind and changes in colony weight, and between wind and hours of flighting.

per day for the two years and the directions and velocities of the wind. The two year means of hours of flighting show that the maximum number hours of flighting (14.2 hours) occurred under calm conditions. 11.7, 10.4, 11.1, 9.9 and 9.7 hours of flighting were recorded by winds of scale 1, 2, 3, 4 and 5 respectively. Thus there was a considerable falling off in the number of hours of flighting with increasing wind velocity. The minor irregularity resulting in a slight increase of scale 3 over scale 2 is probably due to the unequal number of the observations recorded in each group.

TABLE XVII

Hours of flighting under different wind conditions during June and July 1945 *and* 1946; *daily average.*

YEARS	FORCE	WIND DIRECTION									MEAN	2 YEA MEAN
		CALM	N.	NE.	E.	S.E.	S.	SW.	W.	NW.		
1945	CALM	14.5									14.5	14.2
1946		14 2									14.2	
1945	1		12.2	7.8		11	12.5	11.7	13.1	10.6	11.4	11.7
1946			14.4	7.9	15.3		14.6	12.4	10.8	9.5	11.9	
1945	2		10 1		11.5		10.5		11.5	10.5	10.8	10.4
1946			13.8			15.8		8.2	10.5	10.6	10.1	
1945	3		7.5		12.3	15 5		10.1	11.4	10.3	10.8	11.1
1946					11.3		9.3	11.1	12.3	11.1	11.3	
1945	4			9			8	7.8	9.7	10.6	9.3	9.9
1946								9 5	12.8	12.3	11.3	
1945	5			9.3				10			9.7	9.7
1946												
1945	MEAN	14·5	9.9	8.4	12.1	13.3	11.4	9.9	11.4	10.5		
1946		14 2	14.2	7.9	13.3	15.8	13.6	10	11.4	10.9		
2 YEARS MEAN		14.2	11.4	8.2	12.5	14.1	12.4	9.9	11.4	10.7		

Analysis of the influence of wind direction on hours of flighting shows that there are considerable differences in effects between the two years. For instance in 1945 maximum flying activity in wind of scale 1 occurred with Westerly winds (13.1 hours) but in 1946 these Westerly winds were associated with flighting markedly less than the average for winds of scale 1. Such differences make it dangerous to draw firm conclusions from records embracing only a small number of days, but it is interesting to note that the six daily records of NE. winds of scale 1 show a very low average number of hours of flighting in both years (7.8 and 7.9 hours respectively) and the two records of moderate SE. winds show a very high average number of hours of flighting (15.8 and 15.5 hours). It would appear that the other variations observed in relation to wind direction are not large enough to be significant.

CONCLUSION AND SUMMARY

Weather factors are interrelated in a complex manner and the correlations obtained by single correlation may differ from more accurate ones obtained by partial correlation. However, the method of direct correlation at least represents a considerable advance over the method of estimating the relationship between two variables by inspection of a graph. All days, irrespective of whether a gain or loss in colony weight is recorded, rainfall or wind are included in the calculation. The conclusions drawn are:

(1) The similarity of the results obtained from the two colonies indicates that the data are reliable.

(2) That the weather factors under consideration have greater influence upon periods of flighting than on changes in colony weight.

(3) The variation in the values of regression from month to month and from year to year are clear from the figures in Tables IV, V, and VI. This shows that seasons show much variation.

(4) There is a close relationship between period of flighting and changes in colony weight.

(5) The relation between different weather factors and changes in colony weight or period of flighting vary considerably.

(6) The activity and food available are also affected by a number of different factors.

(7) The night loss in weight bears a close relation to day's gain during honeyflow period.

(8) It seems that prevailing temperature does not affect the rate of night loss in weight.

(9) Main food sources at Rothamsted are probably white clover and lime (*Telia vulgaris*).

Temperature

(1) Low temperatures have a direct effect in retarding the gain of the honeybee colony as well as shorting the period of flighting.

(2) The lowest maximum temperature range within which colonies of honeybees at Rothamsted gained in weight during the honeyflow period was 60-64 °F., while at the highest temperature observed 80-84 °F. the colonies also put on weight.

(3) The temperature at which the greatest average gain in colony weight was recorded for two years 1945 and 1946 was between 75-79 °F.

(4) A highly significant positive correlation exists between maximum temperature and daytime as well as 24 hours net gain or loss in colony weight. The influence of maximum temperature is more apparent on daytime changes in colony weight than on changes over the 24 hours. Variation

in the regressions of daytime and 24 hours changes in colony weight may be attributed to the conditions of food sources.

(5) A highly significant positive correlation coefficient was found between maximum temperature and number of hours of flighting. There is no variation due to seasonal influences in the regression of number of hours of flighting on maximum temperature.

(6) The correlation coefficients found between maximum temperature and changes in colony weight and duration of flighting were higher than those found between the latter two factors and any of the other weather factors.

(7) Temperature seems to be one of the most important weather factors influencing the behaviour of honeybees.

Daily range of temperature

Cool nights followed by warm days or high daily range appear to produce greater activity and a correspondingly greater gain.

Ground temperature

Ground temperature is closely related to the change in colony weight when taking the data for whole year and particularly during June. The results obtained during the second year confirm the results obtained during the first year. The similarity in the results obtained from the data of changes in colony weight and hours of flighting in relation to ground temperature are in agreement with the close relationship between flighting and gains in colony weight.

Solar radiation and sunshine

(1) No relation was found between the total solar radiation measured by a Callender electric recorder and changes in colony weight during the honeyflow period.

(2) Duration of sunshine had marked influence on the changes in colony weight.

(3) Variation in the regressions of changes in colony weight on hours of sunshire was obvious in different years and the various months in the honeyflow.

(4) Solar radiation and duration of sunshine have a profound influence on number of hours of flighting.

(5) The striking similarity in the regressions obtained during different years and different months for the hours of flighting on hours of sunshine was quite clear. This evidence indicates that hours of sunshine have a regular influence on hours of flighting.

(6) Under the conditions existing at Rothamsted there was a tendency for larger gains to be associated with longer hours of sunshine.

Air moisture

Correlation of moisture in the air measured as relative humidity % or due point °F. with changes in colony weight and period of flighting shows that :

(1) A dry atmosphere has a beneficial effect on changes in colony weight and prolongs the duration of the period of flighting.

(2) Dew point (9 h. a.m.) seems to have no association with the number of hours of flighting, while it has a greater influence on changes in colony weight than has relative humidity.

Rain

From the data in hand it is apparent that the amount of rain with its even distribution round the year at Rothamsted make it relatively less important than other weather factors in its influence on food sources.

The negative correlation although not significant is enough to make it clear that excess rain can be regarded as unfavourable to increase in colony weight whether it affects the food sources themselves or prevents the bees from working on them.

Flighting of bees is found to be closely related to rainfall and also to the number of rainy days, but it is much more closely related to the rainfall which occurs during the daytime. Negative and highly significant correlation coefficients in general were obtained between day rainfall (6 a.m. to 6 p.m.) and hours of flighting.

Barometric pressure

(1) It seems that high atmospheric pressure favours the number of hours of flighting and hours of flighting at similar barometric levels tend to increase when the pressure is falling.

(2) Although there is a slight variation between data obtained during 1945 and 1946 for both daytime and the net changes in colony weight yet data for the two years combined for each dependent variable under the various barometric conditions show that high atmospheric pressure was accompanied by an increase in colony weight.

The differences which existed between the two different years may have been due to the unequal distribution of the different categories of the barometrical conditions during the two successive years.

(3) Study already has shown the minor part that barometric pressure

plays in influencing the behaviour of the honeybee. Although a relationship exist between fluctuations in barometric pressure and flighting it seems that the characters (due to the other weather factors) associated with the various types of barometrical conditions have more influence than barometric pressure itself.

Wind

The results demonstrate a very marked negative relationship between wind velocity and changes in colony weight and a significant but less marked negative relationship between wind velocity and hours of flighting.

It seems clear that the contradictory results concerning the effects of wind direction on nectar collection and length of flighting are due to the fact that the various directions of the wind do not directly affect the bees. The other environmental factors which accompany the wind are much more important. This is probably why NW. and NE. winds, characteristically associated with cooler weather, produced the smallest gains in colony weight and least flying activity, and SE. winds, characteristically associated with warm dry weather, were associated with substantial gains in colony weight and most flighting on two of the three occasions of which they occurred.

The differences which existed between the figures for the two years may be due to other environmental factors and to the unequal distribution of the different wind conditions during the two successive years.

Although the influence of the prevailing wind during the honeyflow period has been studied to a small extent, yet it is clear that the trends each year resemble one another and that the sub-division of the data into the various categories described renders possible the analysis of the influence of such weather factors upon bee behaviour.

ACKNOWLEDGMENTS

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Seasonal variation, the distribution of the changes in honeybee colony weight and the metabolic rate during a period of inactivity

(with 5 Text-Figures and 6 Tables)

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CONTENTS

Introduction and review of literature. — Discussion of the Rothamsted data. — The main weather factors and the total yearly net gain in colony weight. — The distribution of the changes in colony weight. — The relationship between monthly mean changes in colony weight and monthly mean hours of fllghting. — Frequency distribution of the monthly means. — The duration of honeyflow season. — The significance of the monthly mean changes in colony weight. — Differences between various monthly mean changes in colony weight. — The magnitude of the gain in colony weight. — June and July the best honey months. — The amount of food consumed by a colony of honeybees during the dearth period. — Periodical trends in the honey production at Rothamsted. — Conclusion and Summary. — Acknowledgments. — Bibliography.

INTRODUCTION AND REVIEW OF LITERATURE

From the data available we are able to determine the average amount of food required to maintain a normal colony during a period of inactivity and also the amount of surplus honey which a colony of bees produces under the conditions at Rothamsted.

Practically nothing has been published regarding these points in England except for a few notes in the Bee-keeping Journals. There has been some discussion in these by practical bee-keepers on why the consumption of stores by a colony should vary from one month to another throughout the year and why these variations should be similar season after season.

Krishnamurti (1940) at Rothamsted studied the changes in weight of a colony of bees during the months of May, June and July throughout an eleven year period. Although his conclusions are in close agreement with mine, it should be pointed out that the method of analysis which he employed might lead to errors with regard to the effects of environmental conditions on a colony of bees. It is clear that it is usual for a colony to

gain considerably in weight during May, June and July and yet to lose a lot of weight during the rest of the year so a study only of the months of honeyflow may lead to inaccurate conclusions when computing the surplus honey during different years. It is clearly better to regard the whole year as a unit so that the net gain or loss in colony weight is taken as an index by means of which to compare one season with another.

Secondly Krishnamurti related the weather conditions of each year with their long-range mean (50 years), but the colony weights only with their eleven year mean, it would have been more accurate to relate both conditions with means of the same period. The gain in colony weight during these three months in each year does not give a correct idea of the nature of these years from the view point of total honey production in relation to weather factors as claimed by Krishnamurti.

DISCUSSION OF THE ROTHAMSTED DATA

In order to make comparisons of changes in colony weight, the net loss or net gain in weight every day was determined, and the average for each month tabulated. Table I shows the monthly means changes in colony weight month by month for the different colonies on balances that were maintained throughout this period (1928-1946 inclusive). The results can best be presented in the form of histograms since by this method one can see simultaneously the records for a number of years. The histograms of the net gain or loss in colony weight of the different colonies during the various years have been drawn to the same scale so that direct comparison can be made between them (Fig. 1).

It has been found that colonies which start the season equal in weight vary in their changes in weight. Whilst colonies of equal strength usually have similar changes in weight (e.g. colonies W.2 and W.5 during 1945 and 1946). The actual, gross, weight of a colony does not give a satisfactory index of colony strength. Although changes in colony weight are controlled to a large extent by the environmental factors, yet differences occurring between colonies of equal weight may be due to the colonies possessing field forces of different sizes. The food gathering ability of a colony depends upon several factors of which the most important is the relative proportion of foraging to household bees. Roots (1945) even goes so far as to claim that a weak colony will sometimes gather relatively more honey than a strong one.

Seasonal trends tend to be in rhythm with the flowering of good nectar plants. Peaks in the yearly curve occurred during the flowering of good nectar plants, whilst a loss in weight occurred during those periods when such flowers were scarce. From Table I and Fig. 1 the remarkable fluctua-

TABLE I

Monthly means net gain or loss in colony weight in ozs.

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUN	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.
1927	—	—	—	—	—	—	11.7	−0.9	−4.5	−3.7	−2.0	−1.8
1928	−1.7	−3.1	−3.1	−3.6	7.3	30.0	63.9	−5.8	−4.8	−2.0	−2.3	−2.1
1929	−3.2	−7.0	−4.0	−9.7	19.8	41.5	12.1	−5.2	−0.6	−1.7	−1.1	−1 7
1930	−2 8	−4.1	−3.5	−3.8	2.4	18.4	5.7	−4.9	−2.1	−2.1	−0.7	−0.7
1931	−1 8	−2 5	−4.2	−3.3	−4.8	14.9	12.8	−4.6	−6.5	−2.5	−1.9	−1.8
1932	−2.1	−3.1	−5.1	−6.9	0.6	27.5	8.9	−1.5	−4.4	−3.4	−2.1	−1.1
1933 W.3	—	—	−1.0	−2 6	5.9	5.6	16.1	−3.2	−0.3	−0.9	−1.2	−1.3
1933 W.4	—	—	—	—	3.9	9.1	20.2	−2.7	−0.1	−1.1	−1.2	−1.0
1933 W.5	−1 7	−2 5	−4.1	−1.0	11.8	10.3	25.9	−2.8	−4.1	−2.5	−2.4	−2.2
1934 W.3	−2.7	−3 0	−3.3	−3.5	17.0	8.8	9.1	−5.1	−2.5	−1.2	−1.6	−1.4
1934 W.4	−1.9	−2 0	−2 2	−2 9	8 0	6.8	10.0	−3 6	−2.6	−1.1	−1.7	−1.6
1934 W.5	−3.3	−4.4	−0.8	−2.0	10.3	14.8	19.2	−4.2	−2.8	−1.8	−2.9	−2.0
1935 W.3	−2.0	−3.0	−4 8	−3.9	−1.4	4.4	22.1	0.5	−3 3	−1.7	−1.2	−1.2
1935 W.4	−1.3	−1.7	−2.9	−3.4	0.1	8.7	40.1	2.7	−3.2	−1.4	−1.4	−1.0
1935 W.5	−3.4	−3.6	−5.3	−3.8	0.5	12 4	46.0	1.7	−4.6	−3.3	−2.2	−1.9
1936 W.3	−2 8	−3.0	−3.6	−3.3	7.2	14.1	9.8	−5.8	−6.6	−1.8	−0.8	−1.0
1936 W.4	−1.8	−2 4	−3.2	−3.7	2 8	−0.2	−2.5	−9.7	−6.2	−1 8	−0.8	−0.9
1936 W.5	−3.4	−4.1	−5.1	−4 7	16.7	12.7	1.7	−6.7	−3.1	−2.1	−0.6	−0.9
1937 W.2	−1.1	−1.8	−1.8	−1 9	−3.4	−0.4	6.6	2.1	−2.3	−1.1	−1.0	−1.4
1937 W.4	−0.8	−1.2	−2.9	−3.8	1.1	6·9	20.2	0.3	−2.7	−1.0	−0.5	−1.0
1937 W.5	−1.6	−2.5	−3.0	−3.7	2.1	6 4	21.7	1.8	−1.7	−1.1	−0.8	−1.5
1938 W.2	−1.8	−1.6	−2.8	−1.9	−3.2	−2.4	7.3	−0.3	−1.7	−3.9	−1.0	−0.9
1938 W.4	−0.9	−1.3	−2.2	−1.7	−2.4	8.1	13 4	−1.6	−1.7	−4.2	−1.1	−0.9
1938 W.5	−2.7	−3.6	−3.3	−3 0	−1.7	7.3	8.4	−2.0	−1.6	−1.8	−1.2	−1.1
1939 W.2	−1.4	−3.2	−2.4	−3.5	12.1	0 5	3.1	−1.4	−2.0	—	—	—
1939 W.4	−1.1	−3.1	−3.1	−3.0	3.3	2.1	22.5	−5.5	−4.6	−1.5	−1.6	−1.1
1939 W.5	−2.3	−3.7	−3.1	−1.8	7.9	1.1	−2.5	−3.1	−4.4	−1.1	−0.8	−1.9
1940 W.2	—	—	—	−3.0	3.1	40.2	11.8	40.0	−4.5	−1.7	−1.3	−1.8
1940 W.4	−2 0	−3.1	−3.8	—	−0 1	26.9	6.8	9.4	−2.3	−1.1	−1.0	−0.8
1940 W.5	−1.9	−1 6	−1.6	−0.9	−1.9	1.6	2.3	22.9	−2.6	−1.2	−1.1	−1 5
1941 W.2	−2.7	−3.9	−4.7	−5.7	0.2	5.3	7.9	−8.7	−5 4	−1.6	−0.9	−1 2
1941 W.4	−0.9	−2.6	—	—	—	5.0	9.3	−7.8	−4.5	−1.5	−0.9	−1.3
1941 W.5	−1.8	−2.0	−2.6	−3.2	−1 2	3.5	7.1	−7.5	−2.9	−1.5	−1.4	−1.2
1942 W.2	−1.2	−0.6	—	—	−6.5	30.5	1.4	−1.1	−4.7	−1.5	−1.6	−1.5
1942 W.4	−1.3	−1.7	−3.6	−4.1	0.9	15.8	3.0	−2.9	−5.1	−1 5	−0 9	−1.0
1942 W.5	−1.7	−2.0	−2 3	−3.8	1.6	—	—	—	—	—	—	—
1943 W.2	−1.4	−2.4	−3.7	−1.3	0.3	0.9	8.3	10.1	−3.2	−2.0	−1 1	−1.4
1943 W.4	−1 1	−1.8	−3 1	−2.9	−4.8	—	—	—	—	—	—	—
1943 W.5	—	—	—	—	1.0	4.2	9.9	11.5	−6.0	−1.6	−1.4	−1 5
1944 W.2	−1.7	−1.6	−0.8	−2.7	5.9	5.1	7.9	−4.2	−5.4	−1.2	−1.2	−1.2
1944 W.5	−2.0	−2.6	−3.4	−0.3	4.1	—	—	—	—	—	—	—
1945 W.2	−0.9	−2.3	−2.5	−1.3	−5.2	33.8	11.7	−0.2	−4.0	−1.4	−1.1	−1.9
1945 W.5	—	—	—	—	—	60.6	14.1	10.1	−3.7	−1.2	−0.7	−1.1
1946 W.2	−2.5	−3.0	−4.3	−4 6	−7.6	1.0	16.0	−2.1	−1.8	—	—	—
1946 W.5	−1.3	−1.6	−4.5	−9.4	−11.2	1.5	15.4	−5 2	−2.4	—	—	—
No.Case	39	39	38	38	42	41	42	42	42	39	39	39
Total	−74	−104 3	−121.7	−127	102.5	495.1	566.4	−72	−143.5	−70.8	−50.7	−52.8
Mean	−1.9	−2.7	−3.2	−3.3	2.4	12.1	13.5	−0.2	−3.4	−1.8	−1.3	−1.4

tions in changes in colony weight will be seen which are due to the influence of weather factors on bee activity as well as directly upon the plants themselves.

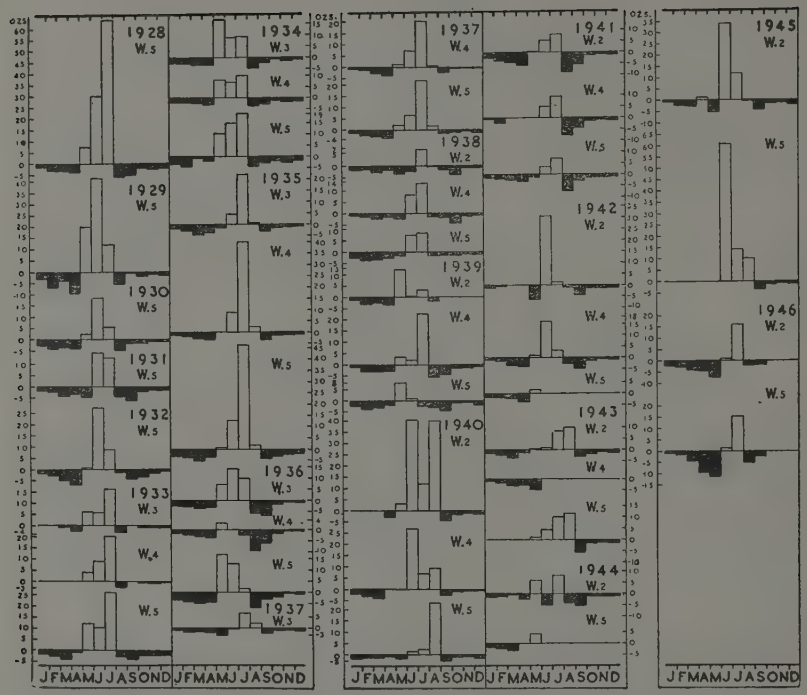

Fig. 1 : Monthly mean net gain or loss in honeybee colony weight, « Home Apiary » Rothamsted 1928-1946.

THE MAIN WEATHER FACTORS AND THE TOTAL YEARLY NET GAIN IN COLONY WEIGHT

Useful information has been obtained from ranking both weather data and the total yearly net gain (or loss in weight) in order of merit. Table II gives the departure from the normal mean of mean air temperature, hours of sunshine, rainfall, the actual number of nights in which minimum temperature on the grass was 30°F. or less, and the order of merit of yearly total net gain in colony weight (data obtained from Table VI). Nineteen points have been granted to the best yearly total net gain in colony weight, the highest departure above the average for the main air temperature and hours of sunshine, 18 to the next and so on. For the rainfall and number of nights in which grass minimum temperature was 30°F. or less the 19 points have been allotted to the highest departure below average.

TABLE II

YEAR	TOTAL NET GAIN OR LOSS IN ORDER OF MERIT	TEMPERATURE		SUNSHINE		RAINFALL		Number of Nights Minimum on grass 30 °F or less	
		BELOW OR ABOVE AVERAGE IN °F	ORDER OF MERIT	BELOW OR ABOVE AVERAGE IN HOURS	ORDER OF MERIT	BELOW OR ABOVE AVERAGE IN INCHES	ORDER OF MERIT	NUMBER OF NIGHTS	ORDER OF MERIT
1928	1	0 5	7	161.3	3	— 0 314	8	103	3
1929	3	0.5	7	296.8x	1	— 1.063	9	119x	1
1930	13	0.4	9	— 22.8	8	0.692	6	87	14
1931	15	—0.3	16	—132.5	14	— 3.096	12	85	15
1932	10	—0.1	13	—174.9	15	— 2.789	11	98	8
1933	6	1.1	5	235.3	2	—10 074xx	19	99	6
1934	7	1.2	3	4.9	7	— 3.440	13	93	11
1935	5	0.8	6	42.2	6	3.594	4	88	13
1936	17	—0.2	14	—270.6	18	4.681	2	108	2
1937	9	0.4	9	—279.3xx	19	6.769 x	1	81	17
1938	16	1.2	3	— 92.4	10	— 5.719	18	99	6
1939	14	0.4	9	—149.4	15	4.076	3	70xx	19
1940	2	—0.7xx	19	69.1	5	1.185	5	100	5
1941	18	—0.6	18	—217.7	17	— 0.059	7	98	8
1942	12	—0 4	17	—126.2	12	— 3.512	14	101	4
1943	11	1.5	2	71.5	4	— 4.487	16	82	16
1944	7	0.4	9	—124 0	11	— 4.680	17	98	8
1945	3	1.7x	1	—128.4	13	— 4 320	15	78	18
1946	19	—0.2	14	— 87.7	9	— 1.440	10	89	12

— = below average; xx = lowest: 3 X = highest

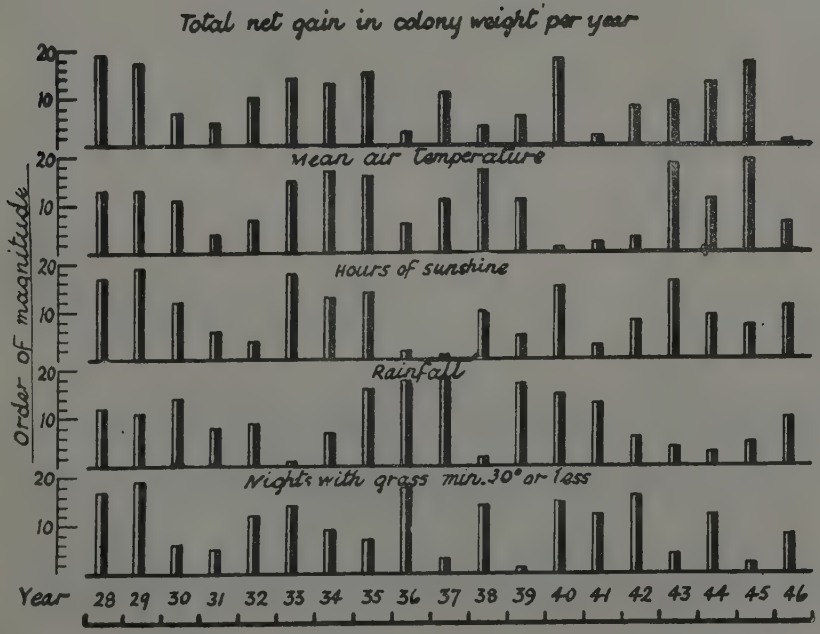
Total net gain in colony weight per year
Mean air temperature
Hours of sunshine
Rainfall
Nights with grass min. 30° or less
Order of magnitude
Year
28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46

Fig. 2 : Comparison between the total net gain in colony weight and weather conditions during 1928-1946 inclusive, arranging them in order.

From the results obtained and presented graphically in Fig. 2 one can see the striking relationship between the total net gain in colony weight every year and the weather factors. The peak of temperature and sunshine almost coincide with the peak in colony weight curve. Peaks in the rainfall curve correspond to depressions in the colony weight curve.

THE DISTRIBUTION OF THE CHANGES IN COLONY WEIGHT

The changes in colony weight have also been plotted in the form of frequency distribution histograms (Fig. 3) in which the records obtained for the different months of the year, during the nineteen year period of investigation are compared, arranged in groups of half an ounce.

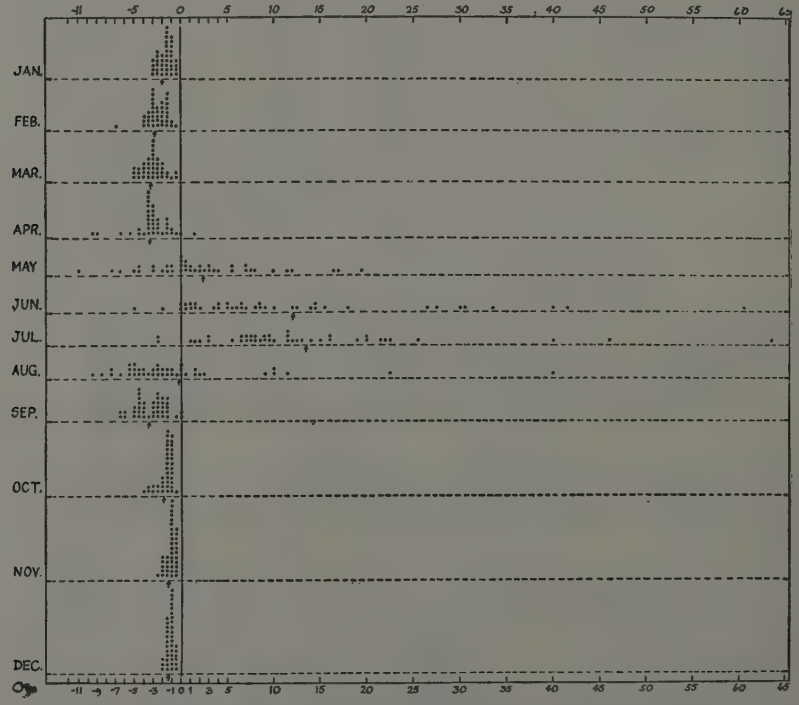

Fig. 3 : Frequency distribution of the net loss and gain in colony weight during the various months of the year (1927-1946).

From Fig. 3 it will be seen that the distribution of changes in colony weight during the period from January to April, and the months of September to December inclusive, are evenly placed about the mean and some

of them give an almost perfect normal distribution. During the months of May to August inclusive, although the shape of the curves tend to follow the same type of frequency distribution, yet they are greatly spread out on account of the variation in the average amount of stores bees brought in.

In all the months of the year except May to August inclusive there is almost always a loss in colony weight (April 1945 colony W.2 recorded 1.5 ounce average gain in weight). From May to August inclusive the honeyflow usually occurs and gains in colony weight are generally recorded.

THE RELATIONSHIP BETWEEN MONTHLY MEANS CHANGES IN COLONY WEIGHT AND MONTHLY MEANS HOURS OF FLIGHTING

Figure 4 A shows the monthly means of the daily average net loss or gain in the colony weight (black lines) and the monthly means of hours of flying activity (faint lines) for the various months throughout the year. Daily average net loss of gain in colony weight for the whole year has been found to be 0.74 ounces per day (approx. 21.3 grams).

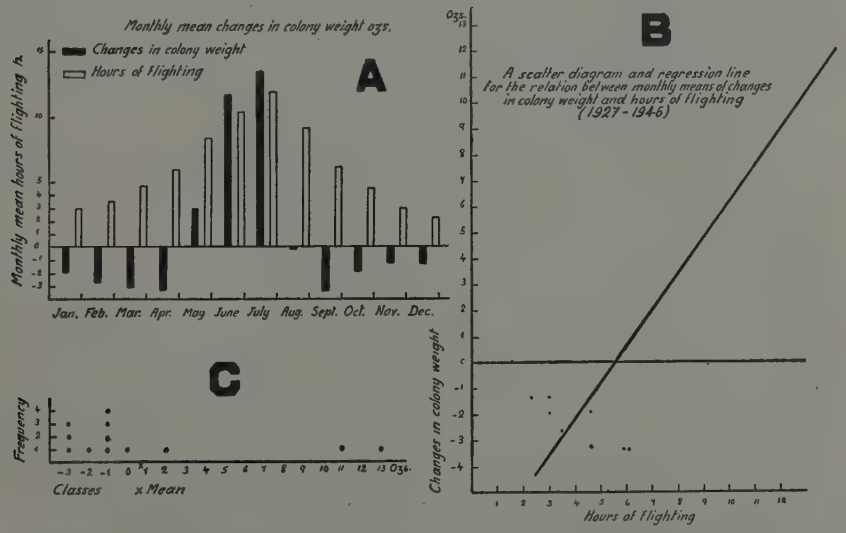
Monthly mean changes in colony weight ozs.
Changes in colony weight
Hours of Flighting
A
Monthly mean hours of Flighting h.
Jan. Feb. Mar. Apr. May June July Aug. Sept. Oct. Nov. Dec.
B
A scatter diagram and regression line for the relation between monthly means of changes in colony weight and hours of flighting (1927-1946)
Changes in colony weight
Hours of Flighting
C
Frequency
Classes
x Mean

Fig. : (A) Histogram showing relationship between monthly mean changes in weight and monthly mean hours of flighting during the various months throughout the year (19 years). — (B) A scatter diagram and regression line for the relationship between monthly means of changes in colony weight and hours of flighting. — (C) Frequency distribution of the monthly mean changes in colony weight (one ounce interval), 1927-1946.

Figure 4B shows a scatter diagram and regression line for the relation between monthly means of changes in colony weight and monthly means of hours of flying activity per day.

It will be seen from Figure 4A that the highest loss in weight occurred during September and was —3.4 ounces and the highest gain in colony weight per day recorded was 13.5 ounces in July.

An examination of this data shows two striking facts, first that there is a definite and close relationship between the number of hours flown and the net loss or gain in colony weight; secondly that when no nectar is available an increase in the number of hours flown is associated with an increase in food consumption which results an increase in the net loss in colony weight but that during honeyflow high gains in colony weight are more frequently associated with an increase in the number of hours of flying activity.

The correlation coefficient between monthly means daily hours of flying activity and monthly means daily net loss or gain in colony weight from the nineteen years data (0.81) is highly significant. That this positive relationship existed between the two variables may indicate that during the dearth period a longer period of flight allows the bees of the colony ample time to defaecate and remove dead bees whilst at the same time the bees consume a remarkably large quantity of stores in order to produce such energy. These factors result the loss in colony weight being greater than usual. On the other hand during the period of the honey flow it is clear that an increase in the number of hours flown gives the bees an opportunity to work longer on honey plants and thus to gather more food.

A regression line calculated (Fig. 4B) from the data under consideration shows that an hours changes in the monthly mean of the daily hours of flying activity above or below the average results in a change of 1.4 ounces in the monthly daily change in colony weight.

The daily average loss in colony weight increase gradually from the beginning of January until the end of April. The spring days are often cool and unfavourable for flight just at a time when the colonies are rearing brood on a large scale. This accounts for the food consumption increasing as the honeyflow period is approached. Any surplus of food gathered during the spring is used up during this period of scarcity. The daily average gain increases throughout May, June and July when it reaches its peak and then proceeds to tail off suddenly. August is the month which connects the honeyflow season with the dearth season and as a general rule a gain in colony weight is recorded during the first two weeks of August, followed by heavy losses in colony weight during the next two weeks, however, it will be seen from Table I that in 12 cases out of 42 there were net gains in colony weight during this month.

FREQUENCY DISTRIBUTION OF THE MONTHLY MEANS

In Fig. 4C the monthly means of changes in colony weight are arranged in the form of a frequency histogram. The mode was —6.2 ounces while the

median was —1.6 ounces. It will be seen that 25 % were above the mean and 75 % were below the mean. The maximum frequencies occupied —1 to —1.9 ounces class.

THE DURATION OF HONEY-FLOW SEASON

It will be seen (Table I and Fig. 1) that at Rothamsted there is really only one honey-flow each season. The duration of the honey-flow varies from year to year but usually includes June and July.

THE SIGNIFICANCE OF THE MONTHLY MEAN CHANGES IN COLONY WEIGHT

From Table III it will be seen that during the period under review May (1946 colony W.5) shows the highest net loss in colony weight per day —11.2 ounces for a single colony. In July 1928 (colony W.5) the highest daily

TABLE III

Monthly means changes in colony weight, number of cases, standard deviation, standard error of the mean, lowest gain or highest loss, highest gain or lowest loss, range, median and mode of the average daily gain or loss in colony weight during the various months of the year for 19 years period.

MONTH	NUMBER OF CASES	MONTLY MEANS IN OZS.	STANDARD DEVIATION	STANDARD ERROR OF THE MEAN S. E.	LOWEST GAIN AN D HIGHEST LOSS DAILY AVERAGE IN OZS.	HIGHEST GAIN OR LOWER LOSS DAILY AVERAGE IN OZS.	RANGE IN OZS.	MEDIAN IN OZS.	MODE IN OZS.
Jan.	39	−1.9	± 0.74	± 0.12	− 3.4	− 0 8	2.6	−1.8	−1.6
Feb.	39	−2.7	± 1.14	± 0.18	-- 7.0	− 1.2	5.8	−2.5	−2.1
Mar.	38	−3.2	± 1.25	± 0.19	-- 5 3	− 0.8	4.5	−3.15	−3.1
Apr.	38	−3.3	± 2.08	± 0 34	− 9.7	1.3	11.0	−3.3	−3.3
May	42	2.4	± 6.66	± 1.03	−11.2	19 8	31.0	1.05	−1 7
June	41	12.1	±14.12	± 2 21	− 5.1	60.6	65.7	7.3	−2 3
July	42	13.5	±12.51	± 1 93	− 2 5	63.9	66 4	9 95	2.9
Aug.	42	- 0.2	_ 8 88	± 1.37	− 9.7	40.0	49.7	−2.4	−7.6
Sep.	42	−3.4	± 1.65	± 0.25	− 6.6	− 0.1	6.5	−3.2	−2.8
Oct.	39	−1 8	± 0.84	± 0.13	− 4.2	− 0.9	3.3	−1.6	−1.2
Nov.	39	−1.3	± 0 55	± 0 09	− 2.9	− 0.5	2.4	−1.2	−1.0
Dec.	39	−1.4	± 0·40	± 0 06	− 2.2	− 0.7	1.5	−1.3	−1.1

average in colony weight 63.9 ounces occurred for a single colony. The range for the highest daily average net gain and the greatest daily average net loss in colony weight is 75.1 ounces.

Ranges for the different months vary considerably. An interesting point is that the ranges of the months October to January inclusive are approximately equal indicating that the environmental conditions which affect the changes in colony weight are similar for each of these months.

In Table III figures representing the median, mode and mean during the months September to April are approximately equal and indicate that the distribution is practically symmetrical. Figures of the months May to August vary remarkably.

DIFFERENCES BETWEEN VARIOUS MONTHLY MEANS CHANGES IN COLONY WEIGHT

In Table IV a comparison of the changes in colony weight during the various months is shown. The data show quite clearly that there were no differences in changes in colony weight between February, March and April when the colony is building up and preparing for the active season.

The difference between November and December was not significant. This

TABLE IV

The significance of the differences between monthly means changes in colony weight

THE TWO VARIATES	DEGREE OF FREEDOM	DIFFERENCE BETWEEN MEANS	t	P	REMARKS
January-February . . .	76	0.8	3.67	< 0.01	Highly significant
February-March	75	0.5	1.92	< 0.1 and > 0.5	Not significant
March-April	74	0.1	0 26	< 1.8	Not significant
May April	78	5.7	5 06	< 0.01	Highly significant
June May	81	9.7	4.06	< 0.01	Highly significant
July-June	81	1.4	0.15	< 0.9	Not significant
July-August	82	13.7	5.79	< 0 01	Highly significant
August-September . . .	82	3.2	2.25	< 0.05 and > 0 02	Significant
October-September . .	79	1.6	3.73	< 0.01	Highly significant
November-October . .	76	0.5	3 13	< 0.01	Highly significant
November-December .	76	0.1	0.92	< 0.4 and > 0.3	Not significant
December-January . . .	76	0.5	3.72	< 0.01	Highly significant
April-September	78	0.1	0.19	< 0.9 and > 0.8	Not significant

may be attributed to the fact that during this cold period the bees consumed food at a constant rate since little external activity could take place and food was only required to maintain life.

From Table IV it will be seen that the difference between the gain in colony weight in June and that in July was not significant. Although in July there was a higher net gain in colony weight, the probability is that a

honey-flow peak will occur equally often in either of these months (June and July).

The data in Table IV appears to support the view that the year can be divided into the four periods familiar between the beekeepers.

THE MAGNITUDE OF THE GAIN IN COLONY WEIGHT

Gains of 10 to 20 pounds in a single day during exceptionally favourable seasons are not uncommon. On the 17th June 1929 the weight of a scale hive at Rothamsted increased 19 lbs. 14.5 ozs. during a period of 12 hours during which the bees were flying strongly, and the loss in colony weight during the succeeding night was 3 lbs. 6.5 ozs., leaving a balance of 16 lbs. 8 ozs. net gain in one day. This day was followed by another in which a further gain of 14 lbs. 14.25 ozs. in colony weight was recorded. From the above figures it is quite clear that it is possible for the gain in weight to be very large but that very seldom do favourable weather conditions coincide with the presence of abundant food sources.

JUNE AND JULY THE BEST HONEY MONTHS

There is no doubt that during the nineteen years under review June and July were the months in which the greatest increases in colony weight were recorded. 48 % of the entire gain in colony weight during the time recorded is credited to July and June has 43 % (Table V). The honey crop is almost negligeable in other months but May and August during some years were productive.

THE AMOUNT OF FOOD CONSUMED BY A COLONY OF HONEYBEES DURING THE DEARTH PERIOD

Farrar (1946, p. 433) in U.S.A. using a colonies housed in Langstroth and Modified Dadant hives showed that good colonies in most northern regions of the U.S.A. consume on an average 50 to 55 pounds of honey from the time brood rearing ceases in the autumn until sufficient nectar is being gathered in the following spring to support the colony a period of approximately 8 months.

Phillips (1946, p. 363) points out that according to the reports of a large number of beekeepers in the northern states of the U.S.A. from 1914-1921 inclusive the quantity of honey consumed per colony during winter amounted approximately to 33 to 37 pounds.

In this present study information has been obtained on food consumption by colonies of bees during the winter months. Under local conditions it has been found that the quantity of food consumed is directly proportional to the

strength of honeybee colony and the environmental conditions prevailing. It is sometimes impossible to determine accurately each colony's carbohydrate requirement during the winter. Therefore, the requirements of the experimented colonies has been estimated from the record of the normal loss in

TABLE V

Periods of various seasonal activity and estimated monthly loss or gain in colony weight at Rothamsted

	MONTH	NET LOSS OR NET GAIN IN THE HONEYBEE COLONY	
		Per day in ozs.	Per month in lbs
Clustering	January	−1.9	−3.7
	February	−2.7	−4.7
Building up season	March	−3.2	−6.2
	April	−3.3	−6.2
	May	2.4	4.7
Honey flow	June	12.1	22.7
	July	13.5	22.2
Preparing for winter	August	−0.2	−0.4
	September	−3.4	−6.4
	October	−1.8	−3.5
Clustering	November	−1 3	−2.4
	December	−1.4	−2.7
	Total gain		53.6
	Total loss		−36.2
	Net gain		17.4

colony weight during the dearth season (Table V). If we take the loss in colony weight as an index of food consumption each normal colony under the conditions appertaining at Rothamsted appears to require about 36 lbs. of carbohydrate stores between August and April. Since some colonies need more than the average, it is wise to see that the bees have more than 36 lbs. of carbohydrate stores for winter use.

It is interesting to note that the rate of consumption of stores during the clustering period remains approximately constant from year to year amounting to between 2.4 and 4.7 lbs. per month (October to February), whilst during the season of colony building up and also the season of preparation for the winter the rate of food consumption is increased to two or three times this level.

PERIODICAL TRENDS IN THE HONEY PRODUCTION AT ROTHAMSTED

A study over a number of years of the net yearly gain in weight of a number of colonies of bees in any given district will give an indication of

the potentialities of the district for honey production. Data from which the honey producing potentialities of the Rothamsted district can be estimated are shown in Table VI. During he 19 years for which records are available there were two exceptionally good years for honey production in which the scale colony produced 81.8-140.6 pounds of surplus honey. The first of these years (1928) was followed by another very good year in which 73 pounds of surplus honey were produced, and the second exceptionally good year, 1940, was followed by one of the worst years for honey production that has ever been recorded at Rothamsted. Eleven years separated these two exceptionally good seasons. In four other years (1929, 1933, 1935 and 1945) more than 40 pounds increase in colony weight was recorded; in two (1934 and 1944) more than 20 pounds and in three (1932, 1937 and 1943) more than 10 pounds of honey per colony. On the other hand there were two years (1930 and 1942) in which only 3.7 pounds and 5.4 pounds gain in weight respectively was recorded, and four bad years (1931, 1936, 1938 and 1939) in which the bees had to be fed to prevent them from dying from starvation.

TABLE VI

Summary of the economic condition year by year, 1928-1946

YEAR	SURPLUS HONEY IN LBS.	MERIT	NUMBER OF COLONY	EXPLANATION
1928	140.6(1)	O O O O	1	(1) Average per colony
1929	73	O O O	1	(2) Minus sign (—) means the bees had to be fed to prevent them from dying from starvation.
1930	3.7	X	1	
1931	(2) - 9.4	X X	1	
1932	13.6	O	1	
1933	43.5	O O O	3	
1934	21.5	O O	3	X = Poor
1935	48	O O O	3	X X = Bad
1936	- 17 2	X X	3	X X X = Worst
1937	15.8	O	3	O = Moderate
1938	—13.3	X X	3	O O = Good
1939	— 4.6	X X	3	O O O = Very good
1940	81.8	O O O O	3	O O O O = Best
1041	—24.9	X X X	3	During the 1 years recordin honeybee colony on a scale:
1942	5.4	X	3	2 years = Best
1943	10.2	O	2	4 » = Very Good
1944	21.5	O O	1	2 » = Good
1945	73	O O O	2	3 » = Moderate
1946	—25	X X X	2	2 » = Poor
				4 » = Bad
TOTAL	457.2			2 » = Worst
MEAN	24.1			

1941 and 1946 were the worst years and about 25 pounds of syrup had to be fed in order to balance the loss of weight recorded per colony.

Burtt (1939) states that in England three good years for honey production have usually been followed by three bad ones but in our district

1939 was a poor year followed by a very good year, which was in its turn succeeded by one of the worst years known.

Krishnamurti (1940) claimed that between 1928 and 1938, there appeared to be an alternate series of short groups of good and bad years for honey production in the south of England. This does not appear to agree with the data now available and even the good years (Table VI) appearing very irregularly.

Howes (1945) claims to show that good, medium and poor honey seasons in the British Isles over a long period of years work out of the ratio of 1:2:1. This conclusion does not agree with any period between 1928 and 1946.

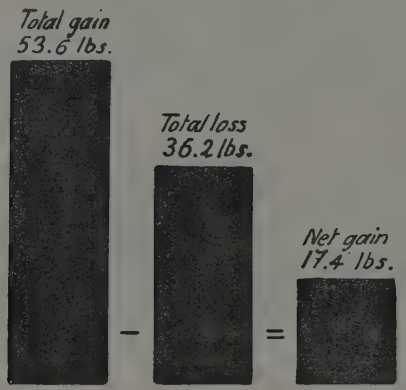

Fig. 5 : Average annual total gain, total loss and net gain in colony weight (19 years period). — Scale 1 cm2 = 1 lb.

In conclusion it will be seen from Table VI that honey-yields at Rothamsted fluctuate from year to year following the fluctuation in the environmental conditions. If there is a periodical trend in the weather conditions, one would expect to find a corresponding trend in the figures for honey-yields but there does not seem to be any.

In Fig. 5 the annual total gain in colony weight, the food consumed for colony maintenances and the supposed surplus honey (17.4 lbs.) which could be extracted during the average year is shown.

CONCLUSION AND SUMMARY

(1) The method employed to determine the daily loss in colony weight during the dearth period and the gain in colony weight per day during the honeyflow season gave satisfactory results.

(2) Colonies of honeybees of different sizes vary in their food requirements and the amount of forage they collect.

(3) The annual cycle of the honeybee can, under Rothamsted conditions, be divided into two main seasons : (A) the death period which includes the months September to April inclusive, and (B) the honeyflow period which usually includes the months May to August. The former period can be subdivided into : (a) the clustering season, (b) the season of building up, and (c) the period when the bees are preparing for winter.

(4) Bees react to the various seasons of the year and the amount of net loss and net gain in colony weight varies accordingly.

(5) A considerable amount of information has been obtained concerning the quantity of food required (at Rothamsted) by a normal colony of honeybees during the dearth period. The quantity of carbohydrate stores that should be left in the hive for colony maintenance during the period between one honeyflow and the next must be not less than 36 lbs. for a colony wintered outdoors and housed in a brood-chamber consisting of a B.S. deep box and a B.S. shallow box.

(6) The capacity of the Rothamsted « Home apiary » so far as honey production is concerned is clearly shown in the records obtained during 19 years and it appears that the average amount of surplus honey that can be obtained per colony per annum is about 17-18 lbs. (8 kilograms).

(7) It has been shown that the average changes in colony weight varies from —3.4 ounces per day during September to 13.5 ounces per day during July.

(8) A highly significant correlation coefficient, 0.81, exists between the degree of activity undertaken by the bees and changes in colony weight.

(9) Changes in colony weight can be correlated with the different environmental conditions associated with each month of the year. The net yearly changes in colony weight follow the weather fluctuations and no periodical trends have been observed.

ACKNOWLEDGMENTS

The writer wishes to express his sincere feeling of gratitude to Dr. C.B. Williams, Head of the Entomology Department and to Dr. G.C. Butler, Head of the Bee Department at Rothamsted for their invaluable help and kind personal guidance.

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Dacus ciliatus Loew, an important new pest attacking Cucurbitaceous plants in Upper-Egypt

[Diptera : Trypaneidae]

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Specimens of fruits of *Cucumis melo dudaim elongata,* locally known as « Qatta Saidi », badly attacked by Dipterous larvae were collected from Kom-Ombo, Upper-Egypt in February, 1953. The authors have bred the flies under laboratory conditions and sent specimens through Dr. A. A. Moursi, Egyptian Agricultural Attaché, Washington, for identification by Dr. R. H. Foote, of Bureau of Entomology and Plant Quarantine of the United States Department of Agriculture. Dr. Foote has kindly identified the fly as *Dacus ciliatus* Loew, which is a new record in Egypt.

It is most probable that the fly has been established in Kom-Ombo before 1953; its damage to cucurbit fruits was most likely mistaken for the similar injury caused by the fly *Leptoxyda* (*Dacus*) *longistylus* Wiedemann, which is also established in the same locality as a serious pest of cucurbits since the year 1947.

M. S. El-Zoheiry, formerly Chief Entomologist and Director General of Crop Protection Department, Ministry of Agriculture, Egypt, in his paper delivered at the Eigth International Congress of Entomology (Stockholm, 1948) stated, that *Leptoxyda* (*Dacus*) *longistylus* feeding primarily on *Calotropis procera* had adapted itself to live directly on the cucurbits.

Dacus ciliatus Loew is very similar and closely related to *Leptoxyda* (*Dacus*) *longistylus* Wiedemann, but the former exhibits some differences in the external characters; the female has a shorter cylindrical tapering ovipositor than that of the female of *Leptoxyda* (*Dacus*) *longistylus.*

The adult of *Dacus ciliatus* (male or female) is an attractive clear-winged fly whose body is light brown with bright yellow markings and dark bands

on its middle section, the thoracic region; and also on the abdomen there are blackish round patches. Complete description will be given in another detailed paper.

Because of the wide distribution of its hosts and the large areas of cucurbitaceous plants grown in Egypt, *Dacus ciliatus* must be accorded first place among the most destructive members of cucurbit pests. A research program was drawn by the authors for thorough investigation of life-history, nature of damage, biological and chemical control of this new pest.

Dacus ciliatus may be more common than *Leptoxyda* (*Dacus*) *longistylus*, because the former has also been found by the authors in June, 1953 attacking *Cucumis sativus fructuminose* Del. locally known as « Khiar », cultivated on the Experimental Farm of the Faculty of Agriculture at Giza.

In the authors opinion, *Dacus ciliatus* is a recent immigrant from Upper-Egypt to Giza Province and seems to be getting gradually more abundant and more destructive especially to late cultivated cucurbit. This is confirmed by a report and specimens of the adult fly sent to us by Dr. A. Maher Ali of the Entomological Section, Ministry of Agriculture, Egypt who has kindly informed us, that during October 1953 *Dacus ciliatus*, which was previously confused with *Dacus longistylus*, has been observed attacking a late cultivation of an acre of cucumber belonging to the Dokki Vegetable Experimental Station at Giza. Dr. Maher stated also in his letter that the attack was so severe that the whole crop was destroyed.

Life-history

The female has a short cylindrical telescopic egg-laying organ protruding from the end of the abdomen. The cucurbit fruit is pierced with this ovipositor and eggs pass through it into the tissues below the surface. The eggs are laid in groups; from 3 to 9 eggs are deposited in a cavity at one time; the actual total number of eggs laid per female is not yet definitely worked out.

The eggs are white, elongated, and elliptical in shape. The newly hatched white maggots burrow deeply inside the fruit and feed upon the pulp and seeds. Full grown larvae desert the fruit and enter the soil to pupate; very rarely pupation takes place inside the fruit. The puparium is cylindrical and of a light yellowish colour; the pupal stage lasts 9-15 days. Low temperature markedly affect the length of the pupal stage. Preliminary observations show that there are several annual broods of *Dacus ciliatus* during the whole year passed in the egg, larval, pupal or adult stage.

Host plants

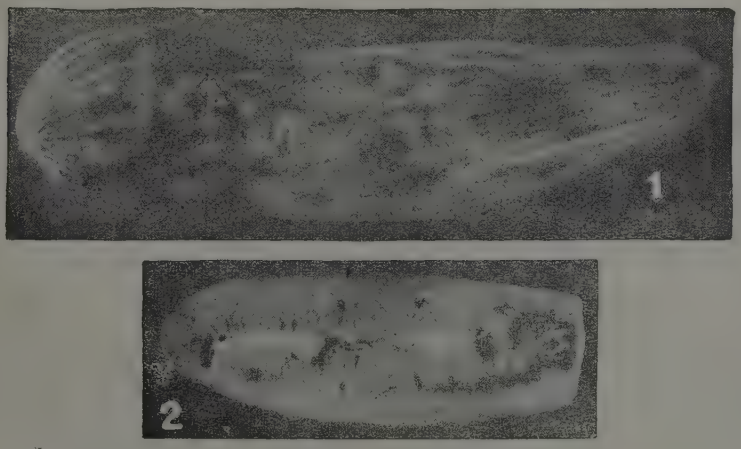
During the present study *Dacus ciliatus* Loew restricted its feeding principally to the following Cucurbitaceae :

(1) *Cucumis melo dudiam elongata* (Arabic name : Qatta Saidi); (2) *Cucumis sativus fructuminose* Del. (Arabic name : Khiar); (3) *Cucumis melo dudaim aegyptica* Sick. (Arabic name: Shammam); (4) *Cucumis melo flexuosus* (Arabic name: Qatta faqus); (5) *Cucurbita pepo ovifera* Sick. (Arabic name: Kosa eskandrani); and (6) *Cucurbita pepo alba* Sick. (Arabic name: Kosa baladi).

Damage and type of injury

The early fall cucurbit crops suffer severely because the fly's life is stimulated and it reproduces rapidly by the hot and dry summer of Upper Egypt. In addition to favourable conditions, the cultivation of consecutive host plants in big areas in Upper Egypt provides uninterrupted food supplies for this pest.

The injury caused to the cucurbit fruits by this fly is of four types : (1) Reduction of grade caused by punctures resulting from the females during oviposition. These punctures spoil the skin and the rind of the fruit which later becomes yellow, wrinkled and withered; (2) the entire fruit is damaged



by the maggots and the pulp rots and decays (see Figs. 1 and 2); (3) destruction and rotting of the seeds; and (4) in addition to the injury caused by the maggots, various molds and other organisms of decay which quickly spoil and disfigure the fruits through the oviposition punctures.

On account of the wide distribution of its host plants and the large areas of cucurbits grown in Upper and in Lower-Egypt, drastic measures should be taken to prevent its spreading from Upper-Egypt to Northern parts

of the Delta. Internal quarantine regulations should be applied in infested areas. The fly population should be reduced by effective measures of control both agricultural (e.g. burning of infested fruits) or chemical (e.g. adult fly baits).

Acknowledgments

The authors take the opportunity to tender their gratitude and thanks to Dr. R. H. Foote, to Dr. P. W. Oman (Division of Insect Detection and Identification, United States Department of Agriculture, Washington), to Dr. A. A. Moursi, to M. S. El-Zoheiry, and to Mr. A. Alfieri, the indefatigable General Secretary of the Fouad I Entomological Society, for their help and valuable advices.

The formation of polyhedra in the gut epithelial cells of virus-infected insects

(with 11 Text-Figures)

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CONTENTS

I. Introduction. — II. Material and Technique. — III. Gross syptoms. — IV. Histology of healthy midgut. — V. The reaction of the midgut epithelium to polyhedral-virus infection. — VI. Polyhedral formation inside the midgut cells. — VII. Infectivity and electron-microscopy. — IX. Summary. — X. Refences.

I. INTRODUCTION

Most investigators who have worked on insect polyhedrosis have shown that virus-infected tissues which show the characteristic pathology and presence of the polyhedra in the nuclei of the cells are the blood cells, hypodermis, fat body, genital capsule and tracheal matrix. In the literature on the polyhedral-virus diseases of insects, only two cases of nuclear polyhedrosis of the gut have been described. The first case is that of the European Spruce Sawfy, *Gilpinia hercyniae* (Hymenoptera : Tenthredinidae) by Balch and Bird (1944), where the pathological process is concerned with the digestive tract and usually results in the complete destruction of the midgut. The second case was recorded by Graham (1948) in the budworm, *Acleris variana* (Lepidoptera: Tortricidae). In addition to the formation of crystal-like bodies (polyhedra), Graham has shown that excessive multiplication of the midgut cells tends to occur in a malignant manner. According to Xeros (1952) several different cytoplasmic polyhedroses of the gut have now been found and cross infection to other species established with them. Xeros suggested that two distinct types of polyhedral diseases exist, nuclear and cytoplasmic polyhedrosis. The polyhedra from nuclear polyhedrosis do not stain with methylene blue, are readily soluble in alkali, and possess membranes. The polyhedra from cytoplasmic polyhedrosis are readily stainable with methylene blue, are less readily soluble in alkali, are without membranes and leave a pitted, « honey-comb » structure after alkali treatment.

In all the previously mentioned cases of gut polyhedrosis, cells other than the digestive cells undergo degeneration and granular break down, often with the invasion by bacteria taking place. It has been suggested that under certain conditions, the epithelial cells of the mid-intestine may show pathological changes. This occurs when *Bacillus bombycis* is present, since this bacterium seems to condition the epithelial cells for virus infection, and vice-versa (Steinhaus 1949).

The present work was meant to clarify, if possible, the role played by midgut cells while undergoing a typical polyhedral infection. Larvae of the alfalfa caterpillar, *Colias philodice eurytheme* Bdvl., and the western yellow striped army worm, *Prodenia praefica* Grote, were chosen for this study. In spite of the fact that the midgut epithelium appears to be the only point at which invasion of the general body cavity occurs, i.e. the virus passes from the midgut cells to the blood cells, fat cells, tracheal matrix and hypodermal cells, yet the midgut cells are nearly always described as unaffected by the polyhedrosis.

II. MATERIAL AND TECHNIQUE

Colias and *Prodenia* larvae were bred in the laboratory right from the egg stage in cylindrical cartons, provided with bouquets of alfalfa tips and kept under room temperature (Steinhaus 1953). When reaching the third instar the larvae were kept singly. To cause a polyhedral-virus infection in the larvae, the provided alfalfa bouquets were first dipped in suspension of the specific polyhedral material in distilled water. Also contaminating the mouth parts of the larvae with a fine camel hair brush, which was dipped into a thick suspension of polyhedral material, gave successful results. Healthy larvae were always kept as means of comparison. Infected larvae were watched carefully, dissected whenever as needed, and blood films and tissue smears were microscopically examined under the fresh and treated conditions. A large amount of serial section cutting was performed on the tissues from any suspected case, either an intact of a dissected specimen.

Blood films and tissue smears were left in 2.5 % iron alum for twelve hours and then transferred to iron haematoxylin for four hours. Then they were washed in another iron alum for a few minutes to wash out the excess stain and left in running water for one hour before they were dehydrated. Only the contours of polyhedra treated in this manner stained blue. But if the polyhedra were first left in an aqueous saturated solution of picric acid for twelve hours, the whole body of the polyhedra became stained blue. Material for section cutting was first fixed in Carnoy's fixative for one hour and then transferred to Duboscq-Brasil for another three hours. Sections were cut 6 μ thick. When they were ready to be stained, they were first left in a saturated aqueous solution of picric acid for twelve hours before

they were washed and transferred to the 2.5 % iron alum for another twelve hours. Then they were stained with iron haematoxylin for twelve hours and excess stain was washed off in another iron alum for a few minutes. Eosin, 5 % in 90 % alcohol, was used as a counter stain. Chromatin and polyhedral particles are stained dark blue while the rest of the cells are light pink with this method. Another method of staining sections was followed. Methylene blue 1 %, stained all tissue, except the polyhedra, in blue, then on transferring to a saturated aqueous solution of picric acid for twelve hours the polyhedra stained a bright yellow (Figure 9).

III. GROSS SYMPTOMS

Infected *Colias* and *Prodenia* larvae of all ages were carefully observed after the first day of infection. First and second instar *Colias* larvae were more susceptible to the infection than *Prodenia* larvae of similar age. They behaved the same under untreated conditions. Dissection and sectioning of such infected larvae was not of any help with regard to the midgut cell infection. Nevertheless, an indisputable abundance of polyhedra was shown in the liquefied carcasses. Later instars of *Colias* and *Prodenia* continued to succomb to the effect of the virus infection without giving any special symptoms of midgut infection. It was only in the fully grown infected larvae of *Colias* that detectable symptoms of the midgut infection became evident externally. On the third or fourth day after infection there appeared a median yellowish spot on the dorsum of the sick larva. This spot kept spreading lengthwise until it occupied all the area of the midgut dorsally. When checking by dissection, it was found that the part of the midgut exactly underneath the yellowish spot was opaque, whitish in colour and its wall was much more swollen than the other part of the midgut, the wall of which was rather transparent and greenish in colour. The swollen area of the midgut spreads backwards and forwards until it involves the whole area of the midgut. Infected *Prodenia* larvae did not show any particular external symptoms of midgut infection owing to their thick skin and dark colour. When dissected, the midgut looked light brown and its contents were a dark brown. Its wall was much thicker and more swollen than the healthy midgut.

IV. HISTOLOGY OF HEALTHY MIDGUT

The epithelium of the midgut in a healthy *Colias* larva is composed of columnar digestive cells, and much smaller regenerative cells, situated in groups at the base of the larger cells and leaning against the muscular coat of the midgut. The nucleus of a healthy digestive cell contains the chromatin material dispersed into several small masses held by a fine reticular sub-

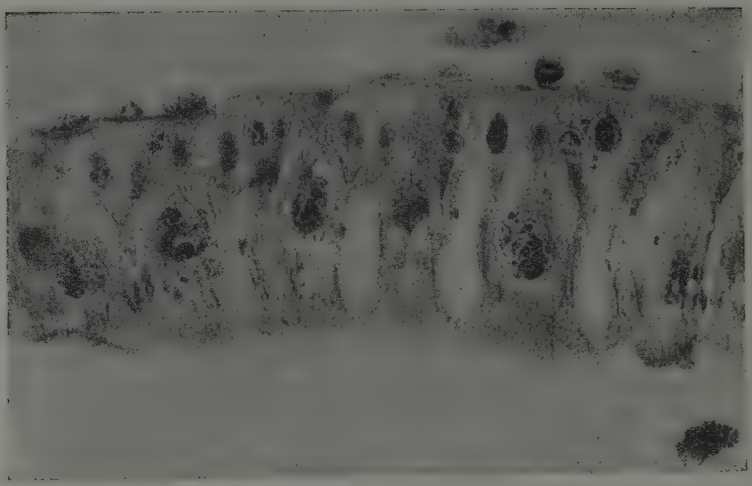

Fig. 1: Midgut epithelium of fully grown healthy *Colias philodice eurytheme* Bdvl., larva (Iron haematoxylin and eosin, × 735).

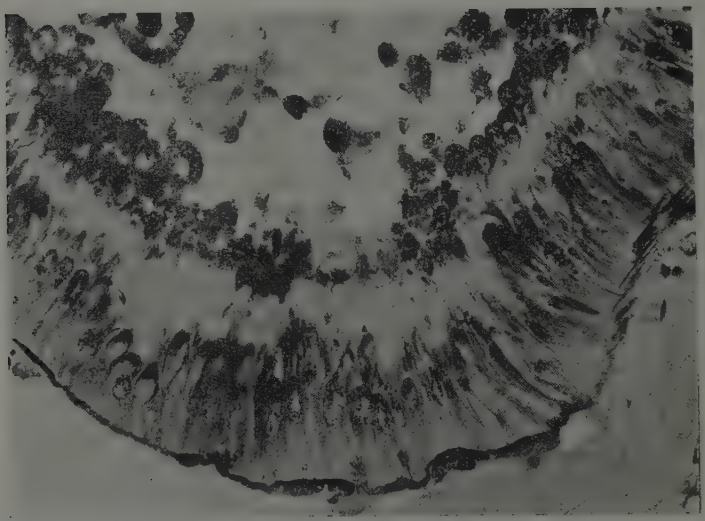

Fig. 2 : Infected midgut epithelium of *Colias* larva, nuclei evacuating their contents inside the tract lumen (Iron haematoxylin and eosin, × 267).

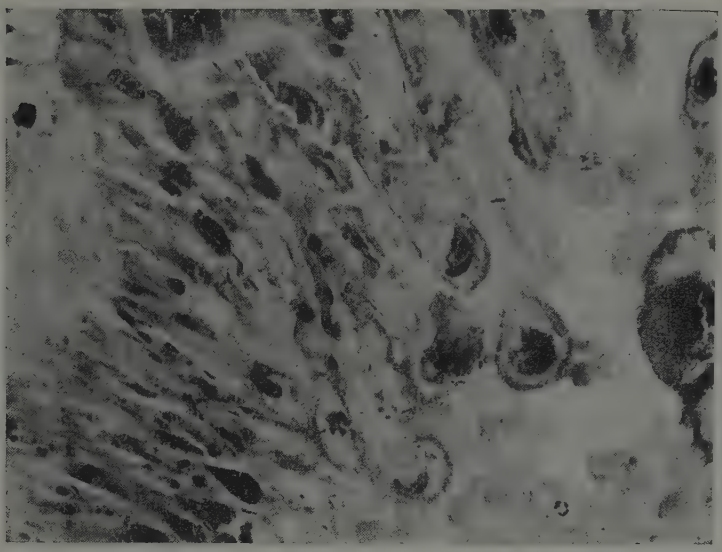

Fig.3: Infected midgut epithelium of *Colias* larva, regenerative action and nipping off infected nuclei inside the tract lumen (Iron haematoxylin and eosin, × 385).

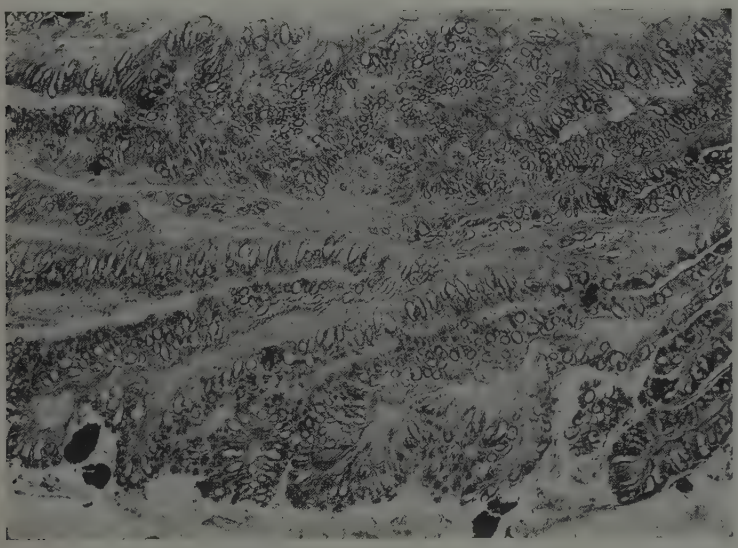

Fig. 4: Tumor growth showing the forming of villi in the midgut of *Prodenia* larva in response to polyhedral-virus infection (Iron haematoxylin and eosin, × 117).

stratum. As mentioned by Bird (1949), the function of the regenerative nidi is : (1) to propagate cells; (2) to replace the large cells when the latter are exhausted; (3) to add to the number of digestive cells during the moulting periods of young larvae; and (4) to replace the digestive epithelium at the time of the last larval moult and during pupation (Figure 1).

V. THE REACTION OF THE MIDGUT EPITHELIUM TO POLYHEDRAL-VIRUS INFECTION

Before the actual formation of the polyhedra in the midgut cells of an infected larva, the reaction of the midgut epithelium takes different forms. The function of the regenerative nidi cells is responsible for the diversity of reaction. It appears that the infection of the midgut cells was overlooked in cases such as the *Colias* and *Prodenia* polyhedroses, due to the diverse reactions of the nidi cells. This diversity of reaction can not be well explained, except that it may depend on the physiological status of the cells at the time of infection and the approach towards the moulting period. In a few cases it was not even possible to trace any disorder in the structure of the midgut cells of definite infected larvae. This superficial non-affected appearance of the midgut epithelium does not refute the possibility of having been previously infected and being replaced rapidly by the regenerative capacity of the nidi cells. Nevertheless, the reaction of the midgut epithelium towards the polyhedral infection is, in most cases, plain and evident, taking one of the three following courses :

(1) Evacuation reaction : in which the infected nuclei move toward the inner border of the midgut, where they evacuate their contents inside the tract lumen. There is no active regeneration from the nidi cells (Figure 2).

(2) Nipping reaction : where active regeneration takes place towards the inner border of the gut. When reaching the lumen, the infected nuclei are nipped off (Figure 3).

(3) Tumor-formation reaction : where very active regeneration takes place in the forming of long villi, with not much evacuation or nipping (Figure 4).

Tumors associated with a virus infection are reported by Bird (1949) as taking place in the midgut epithelium of the sawfly larva of *Gilpinia hercyniae*, where the virus affects only the digestive cells of the midgut epithelium. According to this author large tumors are formed only when the larva becomes infected just prior to the last larval moult. As previously mentioned, the swelling of the midgut wall was only noticed during the last larval instar of both *Colias* and *Prodenia* where it started on a median spot of the midgut and spread up and down along the tract to include the whole area of the midgut. In this work on *Colias* and *Prodenia*, the midgut epithelium is not the only infected tissue, as in the case of *Gilpinia hercyniae*,

but infection starts in the midgut and later is transferred to the other susceptible tissues. While the virus infection was taking its course through the midgut epithelium, blood films and other tissue smears showed very few free polyhedra, if any at all. Thus it was necessary to follow the course of infection through tissues, other than the midgut epithelium, through section cutting and comparing the stages of infection reached by the tissues surrounding the midgut epithelium with the condition of the midgut epithelium itself, from the same larva and in the same section. In confirmation with other authors' work concerning the early disorders happening to the infected nucleus, the first symptom of polyhedrosis is that of the nucleus getting larger in size at the expense of its cell area. Then the chromatin material coagulates into one or more masses which become more rounded in the case of hypodermal cells and of a blotchy shape in the case of the fat cells. These chromatin masses are darkly stained with iron haematoxylin while the rest of the nucleus does not stain (Figure 5). The nuclear and other cell changes are more difficult to observe in the midgut cells because of the regenerative action of the nidi cells.

Later the darkly stained chromatin mass beings to fade out as if it had been used up, while the rest of the nuclear material becomes finely granular and starts to pick up a pale blueish colour. At the end, the chromatin mass fades out completely or almost completely and the nuclear content becomes divided into polyhedral bodies of uniform size in each nucleus but differing among the other nuclei. These polyhedral bodies pick up more and more of the blue stain as they proceed along their development.

VI. POLYHEDRAL FORMATION INSIDE THE MIDGUT CELLS

To discern the actual formation of polyhedral bodies inside the midgut cells, it was necessary to dissect the infected larvae which showed the full external symptoms, previously described, in fully grown *Colias* larvae. Section cutting through the opaque white swollen midgut epithelium showed great cellular proliferation. This thickness of the epithelium consisted of ten or more cells, in continuous succession, which indicates a great capacity of regeneration (Figure 6).

No free polyhedra were discovered in the blood films, fresh or treated, of these infected larvae. Careful microscopical examination has shown that all cells of such infected midgut epithelium contained fully formed polyhedra heavily crowded into the nuclear spaces (Figure 7).

Nuclei of fat cells and hypodermal cells of the same insect contained fully formed polyhedra very much like those in the midgut cells (Figure 8).

It is worth noting that, in spite of the fact that virus contamination is carried from the inside (midgut) to the outside (fat bodies and hypodermis), in most cases it is the hypodermal cells which show more advanced stage of

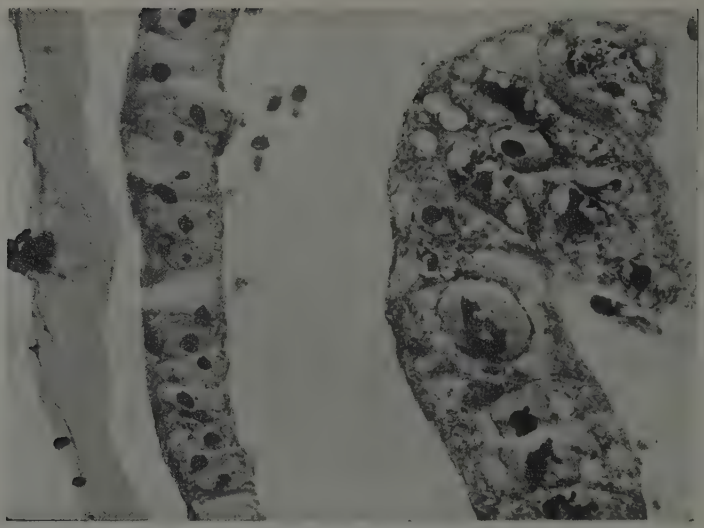

Fig. 5 : Chromatin coagulation and pycrosis in the early stage of polyhedral-virus infection in fat and hypodermal cells *Prodenia praefica* larva (Iron haematoxylin and eosin, × 425).

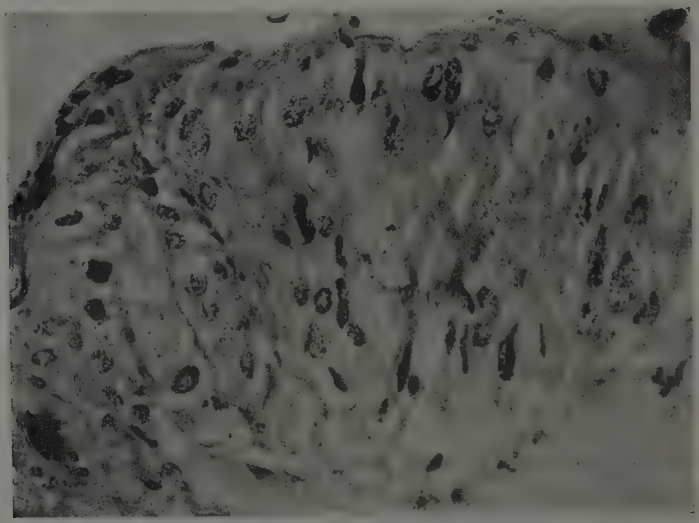

Fig. 6 : Cellular proliferation and polyhedral formation inside the midgut cell of *Colias* larva (Iron haematoxylin and eosin, × 245).

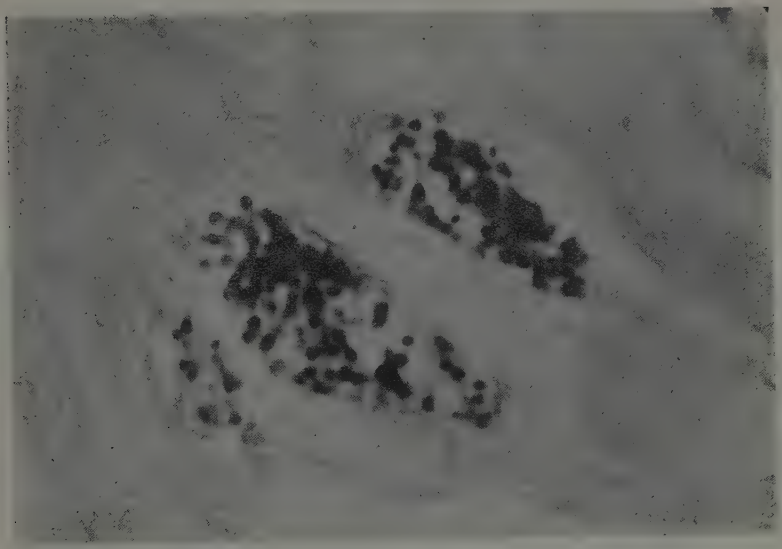

Fig. 7: Two nuclei of the epithelium of Figure 6 under oil emersion magnification to show completely formed polyhedra, in the midgut of *Colias* larva (Iron haematoxylin and eosin, × 2000).

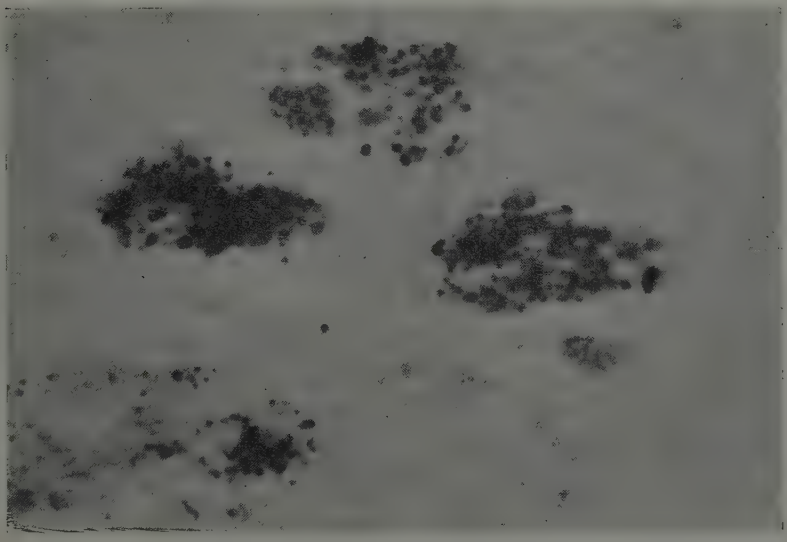

Fig. 8: Fat cells nuclei containing fully formed polyhedra to be compared with the other polyhedra in the midgut cell nuclei of the same *Colias* larva and which appear in Figure 7 (Iron haematoxylin and eosin, × 2000).

polyhedrosis than the fat body or blood cells. The fat cells may be still intact while the hypodermal cells are completely distorted (Figure 9).

As the fore- and hindgut do not play any active part in food digestion and are lined by a cuticular layer, so they are saved, to a great extent, from being affected by polyhedrosis. Yet the nearby cells of both the fore- and hindguts were observed to suffer the same fate as that destined for the midgut cells. During the late stage of polyhedrosis, the extended cells of the hind gut epithelium looked distorted and full of polyhedra (Figure 10).

Midgut epithelium in larvae which showed complete symptoms of polyhedrosis was always disintegrated. Scores of sections of late stages of polyhedrosis were examined and in none of them was the author able to identify a real cellular structure of the midgut epithelium. To remove any suspicion concerning the effect of histolysis which might take place under such conditions, it was necessary to find out the critical stage of infection where fully developed polyhedra had been formed inside the nuclei of intact fat and hypodermal cells, yet degeneration of the midgut epithelium as a result of the prior polyhedral infection had taken place (Figure 11).

VII. INFECTIVITY AND ELECTRON-MICROSCOPY

Infected midgut tracts were dissected out of fully grown *Colias* larvae showing the external symptoms. The food residue was disposed of and the midguts were cleaned carefully in distilled water. Then they were blended in fresh distilled water and the result was a milky white suspension. When smears of such suspension were examined, they showed the characteristic *Colias* polyhedra, identical in shape and size. Other smears were stained either by iron haematoxylin or by picric acid and these polyhedra of the midgut picked up the blue stain of the haematoxylin and the bright yellow of the picric acid. The suspension was used to contaminate either food or mouth parts of *Colias* larvae of different ages and in all cases it caused them to die after showing the identical symptoms of polyhedrosis.

Midgut polyhedrosis suspension of *Prodenia* larvae had the characteristic light brown colour. It gave also the microscopical identification of polyhedra and caused successful infection. Both *Colias* and *Prodenia* midgut polyhedra were examined in the fresh state by the phase contrast microscopy, and they proved to be refractive to light. When the midgut polyhedra were treated by the alkali dissolving process, the polyhedra which stayed in distilled water for some hours resisted dissolving. Fresh *Colias* polyhedra when treated with fresh .01 NO NaH dissolved quite readily within five minutes. *Prodenia* midgut polyhedra needed stronger alkaline to be dissolved.

Dissolved midgut polyhedra were examined under the electron microscope. They looked mostly empty; in a few cases, they contained a few number of virus particles. In most cases, the virus particles escaped outside

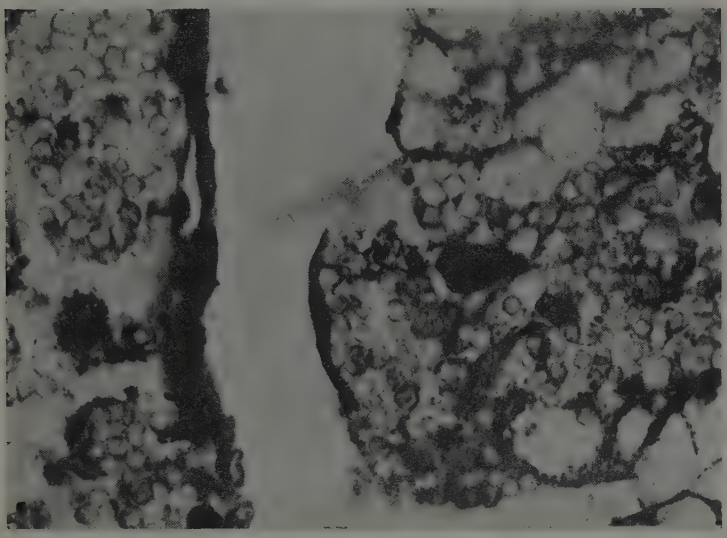

Fig. 9 : Polyhedra formed inside the fat cells (right) and causing hypodermal cells to be completely distorted (left) in a *Prodenia praefica* larva (Methylene blue and picric acid, × 840).

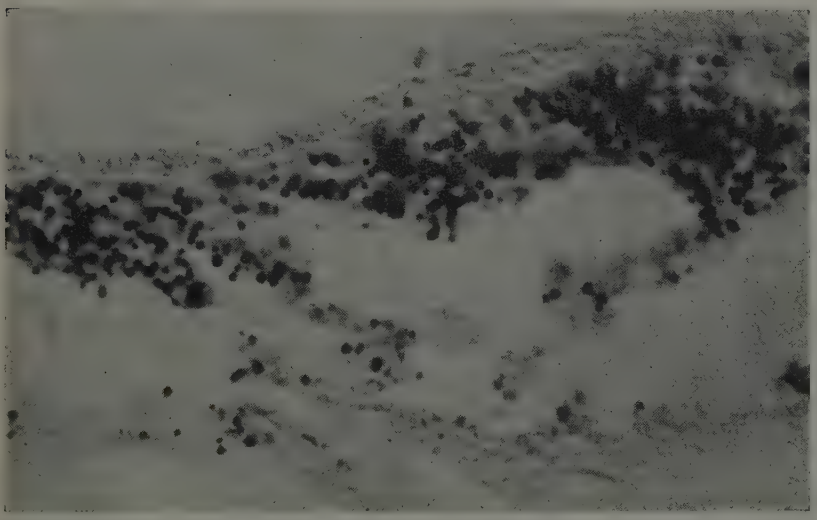

Fig. 10 : Hind gut cell in *Colias* larva containing fully formed polyhedra (Iron haematoxylin and eosin, × 1460).

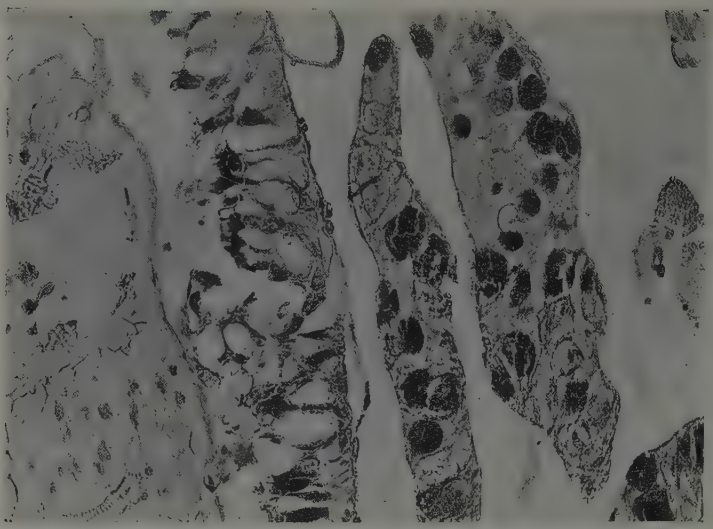

Fig. 11 : Intact fat cell nuclei containing fully developed polyhedra (right) while the midgut epithelium is distorted (left), in *Colias* larva (Iron haematoxylin and eosin, × 235).

their polyhedral membranes. Further electron-microscopy would be worthwhile.

VIII. SUMMARY

1. Two cases of nuclear polyhedrosis have been recorded in the literature to take place in insect midgut. In the two cases, only the midgut epithelium is affected while other tissues undergo degeneration.

2. Polyhedrosis in *Colias philodice curytheme* Bdvl. and *Prodenia praefica* Grote was studied to clarify the reaction of the midgut epithelium to polyhedrosis infection.

3. Midgut epithelium reacted diversely, cell nuclei evacuating their nuclear contents, nipping or breaking off the inner cells into the tract lumen or forming malignant tumors in the shape of long villi.

4. In the case of late infection, the midgut region is caused to swell owing to excessive regeneration which causes the epithelial wall to become very thick. Nuclei of all the cells contain fully developed polyhedra.

5. This study shows that midgut epithelium becomes infected during polyhedrosis before the infection is turned to other susceptible tissues. Such observation may have been overlooked owing to the fact that nidi regenerative cells have an active part in getting rid of the midgut cells that are infected.

6. Midgut polyhedrosis proved to be infectious and identical to its specific polyhedrosis. The polyhedra dissolve in weak alkali but the virus particles usually escape outside their enclosing membranes after these are dissolved.

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